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37th INDIAN SCIENCE CONGRESS, POONA, 1950.

GENERAL PRESIDENT : PROF. P. C. MAHALANOBIS, F.R.S.

Address of the General President : 2 January 1950.

WHY STATISTICS ?

I naturally feel honoured at my election as General President. I remember, several years ago, I discussed with a friend of mine, at that time a member of the Executive Committee of this Association, the possibility of having a separate section for statistics. My friend, who has been always appreciative of the importance of statistics, readily agreed to have an informal talk with his colleagues. A little later he informed me that there was no chance of my proposal being accepted, and with a smile told me that some of his colleagues had remarked: "If statistics is to have a section, you may as well have a section for astrology." Evidently, statistics and astrology were bracketted together in the mind of many of our scientists. The forecasting of future events is, of course, a common feature; and the basis was felt to be equally unscientific. And yet, the section for mathematics was converted into the section for mathematics and statistics in 1942; a separate section was created for statistics in 1946; and this year, a person engaged in statistical work has been elected General President. I am aware I have not been accorded this honour because of my personal attainments. I accept it as a mark of recognition of the growing importance of statistics.

2. A great change has taken place in the climate of scientific and public opinion about statistics. One may ask how has this change been brought about? In other words, why is importance being increasingly attached to statistics? It may be appropriate, therefore, to try to explain: Why statistics?

DESCRIPTIVE STATISTICS

3. Historically modern statistics is the result of the fusion of two originally distinct disciplines—one primarily descriptive, concerned with the collection of data; the other essentially analytic, associated with the concepts of chance and probability. From time immemorial men must have been compiling information for peace and war. Statistics is in this sense as old as statecraft.[1] At each upsurge of social and political development or during war, there is a rapid growth and expansion of statistical practice. I shall give three examples from my own country.

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[1] Harald Westergaard noted : "Etymologists may find the root of the word 'statistics' in the Italian word *stato*, and a *statista* would thus be a man who had to do with the affairs of the State. "Statistics" would consequently mean a collection of facts which might be of interest to a statesman, whether they were given in the form of numerical observations or not." (*Contributions to the History of Statistics*, London, 1932, p. 2).

Arthasāstra of Kautilya: 3rd Century B.C.

4. The *Arthasāstra* of Kautilya[2] claims to date from the period 321-296 B.C., that is, the Maurya period which reached its peak in the time of the great Asoka. It contains a detailed description for the conduct of agricultural, population, and economic censuses in villages as well as in cities and towns on a scale which is rare in any country even at the present time. The detailed description of contemporary industrial and commercial practice points to a highly developed statistical system. In Chapter XXXV (p. 158), instructions are given about the classification of villages. Specific directions are also given for a detailed census of land and field (p. 158):

> "It is the duty of Gopa, village accountant, to attend to the accounts of five or ten villages, as ordered by the Collector-General.
>
> "By setting up boundaries to villages, by numbering plots of grounds as cultivated, uncultivated, plains, wet lands, gardens, vegetable gardens, fences (vata), forests, altars, temples of gods, irrigation works, cremation grounds, feeding houses (sattra), places where water is freely supplied to travellers (prapa), places of pilgrimage, pasture grounds and roads, and thereby fixing the boundaries of various villages, of fields, of forests and of roads, he shall register gifts, sales, charities, and remission of taxes regarding fields.
>
> "Also having numbered the houses as tax-paying or non-taxpaying, he shall not only register the total number of the inhabitants of all the four castes in each village, but also keep an account of the exact number of cultivators, cowherds, merchants, artisans, labourers, slaves, and biped and quadruped animals, fixing at the same time the amount of gold, free labour, toll, and fines that can be collected from it (each house)."

5. In Chapter XXXVI (p. 160) similar instructions are given about the statistics of the Capital City (p. 160):

> "A gopa shall keep the accounts of ten households, twenty households, or forty households. He shall not only know the caste, gotra, the name, and occupation of both men and women in those households, but also ascertain their income and expenditure."

6. One striking feature in the *Arthasāstra* is the emphasis on the need of checking and verification by independent agents working in secret without the knowledge of the original enumerators (Chapter XXXV, p. 159):

> "Spies, under the disguise of householders (grhapatika, cultivators), who shall be deputed by the collector-general for espionage, shall ascertain the validity of the accounts (of the village and district officers) regarding the fields, houses and families of each village—the area and output of produce regarding fields, right of ownership and remission of taxes with regard to houses, and the caste and profession regarding families.
>
> "They shall also ascertain the total number of men and beasts (janghagra) as well as the amount of income and expenditure of each family."

7. Detailed instructions are given in other places about the standards of weights and measures, measurement of space and time; national accounts;

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[2] Translated by Dr. R. Shamasastry, 3rd edition, Wesleyan Mission Press, Mysore, 1929.

and the duties of Government Superintendent in charge of multifarious departments such as the treasury; mining operations and manufacture; commerce; forest produce; tolls; weaving; agriculture; livestock; armoury; infantry; chariots; etc. etc. Specific duties are in fact described for no less than 25 different Superintendents by designation.

Ain-i Akbari : circa 1590 A.D.

8. In another peak period of Indian history, in the time of the great Akbar, we find a description of a highly developed statistical system in *Ain-i Akbari* which is practically the administration report and statistical returns of his government as it was in 1590 A.D. In the introduction to the second volume, H. S. Jarrett observed:[3]

> "It will deservedly go down to posterity as a unique compilation of the systems of administration and control through the various departments of Government in a great empire, faithfully and minutely recorded in their smallest detail, with such an array of facts illustrative of its extent, resources, condition, population, industry and wealth as the abundant material supplied from official sources could furnish."

9. The approach is definitely scientific. For example, the author discusses various standards for the measurement of length, and describes how Akbar "seeing that the variety of measures was a source of inconvenience to his subjects, and regarding it as subservient only to the dishonest, abolished them all," and brought the *Ilahi gaz* in general use (Vol. II, *Ain* VIII, pp. 58-61). In the same way standards are developed for the measurement of land. It is noted that "a measure of hempen rope twisted which became shorter or larger according to the dryness or moisture of the atmosphere" (pp. 61-62). Therefore, "the *jarib* was made of bamboos joined by iron rings. Thus it is subject to no variation, and the relief to the public was felt everywhere while the hand of dishonest greed was shortened." (*Ain* IX, pp. 61-62). Other measures of area and volume as well as the standardisation of currency receive minute attention.[4]

10. In *Ain* XI (pp. 62-63) a detailed account is given of the classification of land based on the yield of crops. A distinction is made between yields in the two seasons 'spring harvest,' and 'autumn harvest.' Furthermore, yields are given for three different grades of soil, "best, middling, and worst;" and the average of the three grades is calculated as "the medium

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[3] English translation by H. Blochmann (Vol. I, 1873) and H. S. Jarrett (Vol. II, Vol. III, 1894) published by the Asiatic Society of Bengal: Vol. II, p. vii.

[4] *Ain-i Akbari* gives the area, revenue valuation, strength of army, and other details for about 15 *subahs* (provinces) comprising over 130 *sarkars* (districts) and over 3000 *mahals* (townships and sub-divisions) extending from Assam and Arakan to Afganistan; the average yield of 31 crops for 3 different classes of land; annual records of rates based on the yield and price of 50 crops in 7 *subahs* (provinces) extending over 19 years (1560-61 to 1578-79 A.D.); daily wages of men employed in the army and the navy; labourers of all kinds; workers in stables, etc.; average prices of 44 kinds of grains and cereals, 38 vegetables, 21 meats and games, 8 milk produces, oils, and sugars, 16 spices, 34 pickles, 92 fruits, 34 perfumes, 24 brocades, 39 silk, 30 cotton cloths, 26 woollen stuffs, 77 weapons and accessories, 12 falcons, elephants, horses, camels, bulls and cows, deer, precious stones, 30 building materials; weights of 72 kinds of wood, etc.

It is no wonder that speaking of Abul Fazl, Jarrett has remarked (II, p. v), that "regarded as a statistician, no details from the revenues of a province to the cost of a pine-apple, from the organisation of an army and the grades and duties of nobility to the shape of a candlestick and the price of curry-comb, are beyond his microscopic and patient investigation."

product of a *bigha.*" For the spring harvest, figures are given for from 10 to 20 crops; and for the autumn harvest, for 20 or 30 crops.[5]

SURVEY OF EASTERN INDIA: 1807-1815 A.D.

11. In the first decade of the 19th century, when the British regime in India was rapidly expanding and growing in strength, a comprehensive survey of Eastern India was undertaken by Dr. Francis Buchanan under orders of the Board of Directors of the Hon'ble East India Company dated 7th January 1807. The terms of reference cover an amazingly wide ground as can be seen from the extracts reproduced in Appendix (1). The Survey was pursued by Dr. Francis Buchanan for 7 years when only a portion of the territories under the Government of Bengal Presidency was investigated. The material was sent to London in 1816, and Montgomery Martin published in 1838, a selection in three volumes comprising over 2400 closely printed pages.

12. The book still makes fascinating reading. To whet your curiosity, I shall describe some of the items collected about the people of Patna city and the surrounding region. Information is given, for example, about the number and proportion of families in different consumption levels such as, families that use milk daily; that use milk in the chief season; that use milk on holidays; that use milk seldom. In the same way, information is given by categories of families according to the use of different kinds of dress, bed-sheets, blankets; the consumption of meat, fish, milk, vegetables, spices, oil, salt, rice, wheat, sweetmeats etc; different kinds of fuel and oil; different types of conveyance; state of education ; etc.

13. The utilization of land is shown by giving the areas separately for a large number of categories such as houses, trees, kitchen gardens, vegetables, etc. As regards agriculture, separate acreage figures are given for the area under 200 different combinations of crops, single and mixed. A general table is given for the value of the produce in the case of commercial crops; and both quantity and value in the case of cereals and food crops together with estimates of the marketable surplus; and number of livestock under different categories together with the annual production of milk with prices.

14. There are tables showing the proportion of rent paid by different sections of the population; the economic position of farmers with proportion of indebted families; and the number of artisans classified into 108 different categories. The manufacture of cotton cloth receives special attention; and detailed estimates are given of the number of weavers; looms; monthly production; earnings and profit for different kinds of cloth. Finally, there are tables of exports and imports (for the region surrounding Patna

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[5] One interesting practice deserves notice. The ten *ser* tax (*Dahseri*) is thus described: "His Majesty takes from each *bigha* of tilled land ten *sers* of grain as a royalty. Store houses have been constructed in every district. They supply the animals belonging to the State with food, which is never bought in the bazars. These stores prove at the same time of great use for the people ; for poor cultivators may receive grain for sowing purposes, or people may buy cheap grain at the time of famines. . . . . They are also used for benevolent purposes; for His Majesty has established in His empire many houses for the poor where indigent people may get something to eat." (Vol. I, 1927, p, 285).

The optional payment of revenue in the form of grain may deserve serious consideration as an alternative method of grain procurement in these days of food rationing in India.

city) in which separate figures are given for 140 different categories of commodities.

15. The report everywhere shows the critical attitude, keen scientific spirit, and the experimental approach of Dr. Buchanan. The wealth and reliability of the information (as far as this can be judged from internal evidence) make this report one of the most remarkable surveys of all times. There is nothing in any subsequent survey in India to approach the one conducted by Buchanan 140 years ago.

16. It is not entirely fortuitous that the three surveys mentioned above were associated with three great periods of political and socio-economic expansion in India. The statistical system is a visible mark of the political framework of each country. The statistical organization, therefore, inevitably follows the rise and fall of the wider administrative system. I shall examine later the position of statistics in the changing conditions of India at the present time.

DEVELOPMENTS IN OTHER COUNTRIES

17. The practice of descriptive statistics gradually developed, with ups and downs, in all countries of the world. Aristotle's work contained references to information about no less than 158 states.[6] Besides public administration, statistics was in much use in commerce. Certain forms of commercial insurance existed in Babylonia, Greece and Rome, and in the middle ages in Italy. By the end of the 18th century, life insurance was becoming prevalent in Western Europe. All this led to important statistical studies. In 1662, for example, John Graunt used the register of deaths (Bills of Mortality) in London to investigate population trends. Since then, in Europe, the study of statistics has been closely associated with actuarial science. On the break-up of the feudal system, the expanding national economies required increasing use of factual information for the formulation of financial, military and political policies. This process has continued down to the present times. In fact, the need of fighting a total war led to an unprecedented expansion in statistical activities in the last ten years to which I shall again refer.

GAMES OF CHANCE AND PROBABILITY

18. I must now turn to the analytic side of statistics. Curiously enough, the first phase of development occurred in connexion with games of chance, particularly the theory of the equitable division of stakes for which early solutions were given by Cardan and Galileo in the 16th century. A little later, Pascal and Fermat developed more general methods on the basis of permutations and combinations. In this way the concept of probability, based on chance, gradually became the subject of much mathematical investigations culminating in the work of Laplace in early 19th century.

THE TOSSING OF A COIN

19. The concepts were fundamentally new and deserve consideration. A simple example is the tossing of a coin (which is assumed to have no bias in favour of turning up either heads or tails). At each throw, it is completely

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[6] H. Westergaard, *Contributions to the History of Statistics*, 1932, p. 4.

uncertain whether the coin will turn up heads or tails. And yet, if the coin is thrown a large number of times (or, alternatively, if a large number of coins is thrown at the same time), it is practically (but never absolutely) certain that heads and tails would turn up approximately in equal numbers. The larger the number of throws (or the number of coins thrown at the same time), the greater is the chance of heads and tails being equal in frequency. Starting from a situation which is entirely indeterminate and uncertain, it is thus possible to reach conclusions with considerable (but never complete) certainty.

20. Several points require to be emphasized. First, it is quite impossible to predict anything about a single toss of a single coin; the prediction (of roughly equal frequency of heads and tails) refers to one whole set of throws. That is, prediction belongs not to any individual throw but to a group or assemblage of throws as a whole. Secondly, the existence of fluctuations or variations is inherent in the very nature of the situation. The relative frequency (that is, the proportion of heads and tails) will never remain exactly equal, but will inevitably fluctuate from one throw to another. Thirdly, because of the existence of fluctuations or variations, it is never possible to make any absolutely certain prediction. For example, however large the number of throws, the coin may turn up heads (or tails) all the time. In principle, even if the coin is tossed a million or a billion (or a larger number of) times, in the very long run, sometimes the coin should (and must) turn up heads (or tails) on the million or billion (or all) occasions.[7] In other words, the prediction is essentially a prognosis which is likely to hold only "in the long run". Fourthly, and this is a very important point, although the prediction is never absolutely certain, it is possible to estimate the limits of uncertainty.

21. The proportion of heads and tails in the tossing of a coin is thus recognized as a statistical variate which is intrinsically subject to variations or fluctuations. The proportion of male and female births is exactly analoguous to the proportions of heads and tails in the tossing of a coin. Before birth, nothing is known about the sex of the individual child, and yet the prediction of a roughly equal frequency of the two sexes can be made with practically the same confidence as the equal frequency of heads and tails.[8] Any inference about the results or any prediction is, therefore, necessarily uncertain; but the margin of uncertainty is itself capable of estimation.

THEORY OF "ERRORS" OF OBSERVATION

22. The position is similar in the case of physical observations. However careful the observer may be, even the simple measurements of the length of a rod have been always found to vary. The average of a number of repeated measurements, however, usually becomes more and more steady as the number of measurements increases. The deviation from the average, *i.e.*, the "error" of each individual measurement is sometimes positive and sometimes negative, and thus behaves like heads and tails in the tossing of a coin. In the 18th century the new concepts of probability began to be applied to the adjustment of astronomical observa-

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[7] This is, of course, very very unlikely to happen which merely means that the probability is extremely small but, in principle, not zero.

[8] Laplace discussed in a memoir of 1781 the number of male and female births in Paris for 26 years (251, 527 males and 241, 951 females) from the point of view of probability. (*Histoire de l'Academie* for 1778).

tions and physical measurements which led to the growth of the theory of errors culminating in the work of Gauss and Laplace.

INDIVIDUAL VARIATIONS AND FLUCTUATIONS

23. If the height of a number of individuals is measured, these measurements again vary. This is equally true for every kind of measurement in biology. Fluctuations or variations are thus intrinsic features of all measurements. In biology, variation itself supplies the material for evolution. Variation is also the outstanding feature in all social sciences.

MEASUREMENTS AND OBSERVATIONS IN SCIENCE

24. A crucial point in the argument has been now reached. All contingent knowledge is based on measurements and observations. Lord Kelvin remarked long ago:

> "When you can measure what you are speaking about and express it in numbers, you know something about it, but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind." [9]

Secondly, every set of measurements (in every field of science—physical, biological and social) is characterized by variation. The aim must therefore be to draw general conclusions from a particular set of measurements, taking variation itself into consideration and not ignoring it.

THE CONCEPT OF RANDOM SAMPLES

25. This is exactly the aim of the theory of estimation and statistical inference. Each set of measurements (with its characteristic variation) is recognized to be only one out of many possible similar sets. Secondly, the totality of all possible sets of measurements (that is, the totality of all possible samples) constitute the "population" or "universe" in which we are interested. In order to reach conclusions about the population or universe, it is clearly necessary that a sample should be representative of the universe. The condition for such representativeness is supplied by the fundamental concept of "randomness." I do not think it is possible to define randomness, but some indication may be given as to its implications. Suppose it is desired to find the average height of a particular group of people. Obviously, it will not do to select individuals who are very tall or very short (or have any other special feature) as the results are likely to get biased. The only safe course is to choose the sample without reference to any previous knowledge about the individuals included in the sample. A random procedure ensures such selection free from bias. Once a random sample is available, it is possible to use the calculus of probability in a valid way to reach general conclusions about the statistical population or universe from which the sample was drawn. The concept of random samples is thus pivotal in statistical theory.

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[9] It is interesting to note that exactly the same idea occurs in the original meaning of the word *sankhyā* (literally, number) in Indian thought. The phrase *sankhyātā* occurs in the *Atharva-Veda* in the sense of "well-known." For more than three or four thousand years in India an intimate connexion has existed between the concepts of "number" and "adequate knowledge." This is why I chose *Sankhyā* as the name of the Indian Journal of Statistics. Further references are given in Appendix (2).

UNCERTAIN INFERENCE

26. Knowledge based on a statistical or random sample is however necessarily incomplete, as it relates to only one out of many possible samples. Conclusions based on a random sample, although valid, must therefore, be necessarily uncertain. It is however the great merit of the calculus of probability that although statistical inference is uncertain, it is possible to estimate a valid measure of the degree of uncertainty. In practice this is usually secured by stating the chance or odds in favour of any particular inference or result being "true" (in the sense of the prediction agreeing with subsequent observations). Suppose extensive agricultural trials have been made to compare the yield of two varieties of wheat. On available evidence, it is then possible to state the conclusion in some such form that the odds are 100 to 1 (or 1000 to 1, or some other odds) that variety A would give a higher yield than variety B. The very form of the statement indicates that, "in the long run", 99 times out of 100, variety A would give a higher yield. Necessarily, therefore once in 100 trials (not in every 100 trials, but again, "in the long run") variety A would give a lower yield. This lower yield may, however, occur in the very first trial. The risk is always there. Not only this, occasionally (or once in 100 trials "in the long run") the prediction must prove wrong. If it did not, then the whole basis on which the prediction was made would itself prove to be wrong. In statistical inference, we thus reach the fundamental paradox:

If statistical theory is right, predictions must sometimes come out wrong; on the other hand, if predictions are always right, then the statistical theory must be wrong.

DEDUCTIVE LOGIC AND MATHEMATICS

27. There is a sharp contrast between statistical or uncertain inference and absolutely certain deductive conclusions. It is a significant fact that the concept of probability developed very late in the history of human thought, as far I know, only during the last two or three hundred years. Deductive logic, on the other hand, is very old. Absolute certainty in fact has long been accepted as the essential characteristic of true knowledge. Pure mathematics is the great historic example. In pure mathematics the conclusions follow inevitably from the premises, and all inferences are absolutely certain. This is why Bertrand Russel described pure mathematics as the class of all proposition of the form: "P implies Q". Deductive logic, therefore, includes the whole of pure mathematics.

DETERMINISTIC VIEWS IN PHYSICAL SCIENCES

28. An invariable sequence of cause and effect is in many ways similar to the formal-deductive process in logic and pure mathematics. In the physical sciences, with the help of the causal principle, the rigour of absolute certainty of mathematical reasoning was accepted for a long time as the ideal model. Newton in writing his great treatise on the principles of natural philosophy deliberately adopted the mathematical form. The possibility of constructing a rational model of the whole universe was a great triumph of the human mind. The growing complexity within the natural, and later in the biological and social sciences, however, led to the gradual replacement of the deterministic-mathematical model by the probabilistic-statistical view. This change was brought about not by abstract reasoning but by the force of events within the field of science itself.

THE ENTROPY PRINCIPLE

29. The Newtonian equations of motion become increasingly unmanageable with the increase in the number of particles requiring to be taken into consideration. It soon became necessary to study the properties of a system comprising a large number of particles. The object now was not to ascertain the motion of each single particle separately, but to investigate the collective properties of all the particles taken together. Concepts and results already available in the theory of errors of observation were pressed into service to develop the kinetic theory of gases. A parallel development of the subject of thermodynamics led to the emergence of the entropy principle. The central concept in the second principle of thermodynamics is again randomness, so that the principle of the increase of entropy is recognized as nothing but the increasing degree of randomness of the physical universe.

THE UNCERTAINTY PRINCIPLE IN PHYSICS

30. A further shift to a statistical model occurred with the development of statistical mechanics culminating in the enunciation of the uncertainty principle by Heisenberg which denied the possibility of absolutely certain knowledge of both the position and the motion of a particle at any given instant. From a theoretical point of view, the uncertainty principle would seem to make physical science essentially statistical in nature. The belief that complete certitude is an essential condition for genuine knowledge, however, still persists in certain quarters. The uncertainty principle is looked upon as belonging to the region of the very small, and therefore not inconsistent with the deterministic view of the world as a whole.

31. I doubt whether the above view is tenable. If science is based on observation and measurement and if each set of measurements is a statistical sample, then all scientific conclusions must be of the nature of uncertain inference (with, in principle, a known margin of uncertainty). The contrast can be clearly seen in the distinction between a mathematical constant and a statistical or physical quantity based on observations. The ratio of the circumference to the diameter of a circle is a mathematical abstraction and, therefore, not subject to any fluctuations. All physical quantities, on the other hand, are based on observation and measurement, and are therefore statistical estimates, necessarily subject to a margin of uncertainty. On this view, all scientific predictions must be characterized, in principle, by a margin of uncertainty.

INDUCTIVE LOGIC

32. It may be observed at this stage that J. S. Mills' empiricism is a departure from rationalism only in form in as much as the aim of Mills' inductive logic still remains "certain" inference. Similar attempts were made much earlier in India to go beyond the purely formal-deductive process. Sir Brajendranath Seal has given an interesting account of the doctrine of inference in the *Positive Sciences of Ancient Hindus* (1915), from which certain extracts have been given in Appendix (3). All these attempts, however, had certitude as the aim of inference. But in Indian thought, it was recognized, in one sense, that this aim is unattainable in practice. B. N. Seal noted for example:

> "Ultimately we all have to fall back on the rational practice of thinking persons, and such persons are always content to act on practical certitude instead of hankering after an unattainable apodectic certainty

> in the affairs of life. This same practical certitude is also the ultimate warrant of the Deductive-Inductive Inference by which we ascertain the characters of things without direct perception and through the medium or instrumentality of a mark."[10]

FALLIBILITY OF SCIENTIFIC KNOWLEDGE

33. I have been trying to place before you the view that all scientific knowledge (being based upon evidence which is formally incomplete) is only probable and never absolutely certain. All predictions based on scientific knowledge must, therefore, be fallible ; and must in fact prove wrong, in the long run, to the anticipated extent. Ernest Nagel observes that those

> "who maintain that our knowledge of matters of fact is "probable" do not thereby maintain that such knowledge is inferior to knowledge of some other kind obtainable by methods different from those the natural sciences employ. On the contrary, they maintain that "probable knowledge" is the only kind of knowledge we can find or exhibit, and that the methods and techniques of the sciences are efficacious and dependable precisely because they make available knowledge of that character."[11]

Thus in the whole field of science, the deductive-mathematical process of absolutely certain inference is being replaced by the probabilistic statistical method of uncertain inference. Ernest Nagel has stated the position very clearly:

> "The long history of science and philosophy is in large measure the history of the progressive emancipation of men's minds from the theory of self-evident truths and from the postulate of complete certainty as the mark of scientific knowledge."[11]

DETERMINISM AND UNCERTAINTY

34. If the probabilistic model is accepted as a closer approach to reality, then interesting consequences are likely to follow in the field of human thought and philosophy. I have no competence to discuss such issues, but one or two observations may not be entirely out of place. All knowledge based on science, and hence all scientific predictions about the future must be recognized, in principle, as uncertain. It is possible however to admit, in principle, that knowledge about the past may be of a deterministic type. The uncertainty about the future may then be interpreted as supplying an opportunity for fresh creation (at least, as perceived by the human mind). In fact, the 'present moment' on this view is the actual occasion of an ever-continuing stream of creation which is marked in rational thought by the transition from a deductive-mathematical to a probabilistic-statistical model of reality.

STATISTICAL METHODS IN THE CONCRETE

35. I have so far considered the statistical method in the abstract. A brief survey of the scope and range of the statistical method in the concrete is also of interest. A convenient way of doing this is to construct a kind of mental map of scientific activities. We may start with a geometrical point at the centre to represent pure mathematics. On the view which

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[10] *The Positive Sciences of Ancient Hindus,* (Longmans, Green & Co., London). 1915, p. 269.

[11] *Principles of the Theory of Probability,* (University of Chicago, U.S.A.) 1939, pp. 3-4.

I have expounded, pure mathematics (being fundamentally deductive in nature) does not itself belong to the field of science; and can be, therefore, appropriately represented by a mathematical point which has "position but no dimension".

PHYSICAL SCIENCES

36. We may draw a small circle round the centre to represent classical physics in which although the form is still mathematical, actual knowledge is based on measurements subject to errors of observation. Fluctuations are, however, small in magnitude so that predictions can be made with great certainty (but are still, in principle, affected by a margin of statistical uncertainty.) A second larger circle may be drawn to represent the area of kinetic theory of gases, statistical mechanics, and thermodynamics. In this region, factors of variation are still amenable to a large degree of control so that the classical method of experimentation (isolating and studying one single factor at a time) is usually available.

BIOMETRY

37. A third larger circle may be drawn to demarcate an area where the factors of variation are more complex and less liable to control. This broadly represents the field of biological variation. In 1900, Karl Pearson coined a new word "biometry" to indicate generally the methods particularly appropriate to this area. The fruitful concept of statistical correlation historically had its origin in this field.[12] In the field of biometry, the fluctuations and variations are themselves of great importance, and often supply convenient yard-sticks for purposes of measurements.

38. During the last 50 years, biometry has become a very large branch of statistical science. It covers practically the whole field of biology and genetics including agriculture and the study of livestock. Biometric methods are also being increasingly used in psychology, education, and the medical and social sciences including the study of the human factor in industry.

39. In dealing with living units, it is usually impossible to use the classical method of isolating and studying one single factor at a time. For example, in studying the increase in the yield of crops due to improved seeds or fertilizers or better methods of cultivation, fluctuations in the fertility of the soil from plot to plot, the influence of weather conditions, and many other factors of variation are always present and can not possibly be isolated. A radical departure had become necessary and took place, about a quarter of a century ago, in the development of the design of experiments and the analysis of variance under the leadership of R. A. Fisher[13]. He himself has observed:

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[12] In 1877 when Sir Francis Galton measured the size of sweet peas in his studies of heredity, he found a "regression" of the size of the daughter seed, compared to the size of the mother seed, towards the general mean. He found the same thing again in connexion with his observations on the height of fathers and sons. These studies led to the development of the theory of regression and correlation by Karl Pearson and others. It is worth noting that Gauss himself had used the product term in his investigations on the theory of errors, but had failed to reach the concept of correlation. The French astronomer Bravais (1811-63) worked on what is in essence the mathematics of correlation, as early as 1846. The concept of regression and correlation, however, did not emerge until 40 years later; and this also, only under the stimulus of the study of biological variations. This perhaps is a corroboration of the view that statistics is essentially an applied science and not a branch of mathematics.

[13] *The Design of Experiments* (Oliver and Boyd, Edinburgh. 1935; 4th Edition, 1947).

> "No aphorism is more frequently repeated in connexion with field trials than that we must ask Nature few questions, or, ideally, one question at a time. The writer is convinced that this view is wholly mistaken. Nature, he suggests, will best respond to a logical and carefully thought out questionnaire; indeed, if we ask her a single question, she will often refuse to answer until some other topic has been discussed."[14]

40. The central aim of the design of experiments is to make experimental observations in such a way that the different factors of variation would have scope to come into play in a balanced fashion so that it would be possible to study the influence of single factors as well as of various combinations of factors at the same time. In fact, R. A. Fisher has remarked: "The more thorough the design of the experiment, the more meaningful is the question asked." Actual experience has shown abundantly the great advantages (in economy of time and effort, and in adaptability) of using appropriate statistical designs in scientific and technological experiments of all kinds.

41. The fact of variation is as universal in the field of industrial production as in biology. Even with machines of the highest precision, no two units are identical in size or other specifications. Usually there is the additional complication of fluctuations in time, but such fluctuations themselves often supply convenient yard-sticks for diagnostic purposes. So long as the fluctuations remain stable, the system may be considered to be under statistical control. W. A. Shewhart[15] used this fundamental concept to develop 'control limits' and 'control charts' to enable the quality or output of manufactured products being maintained at a desired level. These methods found wide applicatons during the war. In fact, without the use of such methods, war production in the United States and other allied countries could never have been sufficiently stepped up. After the war, the use of statistical 'quality control' is steadily increasing all over the world, and a beginning has been made in a small way in India also.

STATISTICAL SAMPLING

42. We may add a fourth circle to demarcate the region in which the appropriate tool is statistical sampling. Factors of variation are now more complex and are usually not amenable to experimental control. This is the field where the traditional method of the exhaustive census or the attempted complete count has been used for a long time. R. A. Fisher has recently described the present position:

> "The words sample and sampling, like the word random, have always been central in the development of mathematical, or theoretical statistics. With the increased understanding and integration of our science they have now, as it were, overflowed from the world of abstractions in which they were generated and refined, and have, in fact, supplied the most adaptable, rapid, economical, and, in the true sense, scientific method of factual ascertainment which we yet possess.
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> "I have made four claims for the sampling procedure. About the first three, adaptability, speed and economy, I need say nothing further. Too many examples are already available to show how much the new

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[14] The Arrangement of Field Experiments, *Journal of the Ministry of Agriculture*, Vol. 33 (1926), p. 511.

[15] *The Economic Control of Quality of Manufactured Products*, (McMillan & Co., London, 1931) ; and *Statistical Methods from the View point of Quality Control.* (Graduate School, Department of Agriculture, Washington, D.C., 1939 ; reprinted 1945).

method has to give in these ways. But, why do I say that it is more scientific than the only procedure with which it may sometimes be in competition, the complete enumeration? The answer, in my view, lies in the primary process of designing and planning an enquiry by sampling. Rooted as it is in the mathematical theory of the errors of random sampling, the idea of precision is from the first in the forefront. The director of the survey plans from the first for a predetermined and known level of precision; it is a consideration of which he never loses sight; and the precision actually attained, subject to well understood precautions, is manifest from the results of the enquiry".[16]

Rapid developments in this field have taken place during the last ten or twelve years in which India has made significant contributions. I shall come back to this subject a little later as it is of great current interest in India.

FREE OBSERVATIONS

43. We may now add a fifth circle to indicate the area in which factors of variation are neither amenable to control, nor to experimentation, not even, in the usual sense of the term, to sample-surveys or sample-censuses. Here the only feasible approach is the patient collection of observations followed by classification and painstaking investigation of possible statistical relationships. Experimentation is no longer possible, but it is still feasible to compare predictions with subsequent observations. Statistical methods are particularly appropriate in this field. I shall give one example from my own experience.

44. In 1926 a catastrophic flood occurred in the Brahmani river in Orissa. An expert committee of engineers appointed by the Government of India reached the conclusion that the bed of the river had risen by several feet and consequently the flood level was likely to be higher in future. The Committee naturally recommended raising the height of the embankments by several feet to give protection against higher floods. At the request of the Government of Bihar and Orissa, I made a detailed statistical study, and found a significant correlation between the rainfall in the catchment area and the height of the river flood in the delta.[17] Using the statistical relationship, I found that the abnormal rise of the river in 1926 could be reasonably ascribed to exceptionally heavy rainfall in the catchment areas. On the basis of such statistical evidence, it was possible to advise Government that there was nothing wrong with the river, and it was *not* necessary to increase the height of the embankments. This advice was given in 1930. The fact that no great change has occurred in the severity or frequency of floods during the last 20 years shows that the statistical findings were correct. Direct experimentation in such cases is out of question ; the statistical method supplies the only valid tool for scientific investigation. Incidentally, in this case, it also saved several crores of rupees.

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[16] Presidential address on "The UN Sub-Commission on Statistical Sampling" at the session on Sampling, International Statistical Institute, Berne, September 1949.

[17] One technical point deserves notice. The catchment area was divided into two portions, and the rainfall in the two catchments were used as two separate variates for correlation with the height of the river flood. *Report on Rainfall and Floods in Orissa Rivers* (submitted in *1930*, and printed by the Government of Bihar and Orissa). The statistical studies made at this time supplied the basic information for the Hirakud Dam, one of the big river valley projects in India.

45. I should like to include in the mental map the field of operational research in which the available information is either too meagre, or is not in a suitable form for the calculation of the probability involved in the problem. In such cases a decision, however, has to be reached by balancing the risks of gain and loss but without the formal use of the probabillty calculus. Operational research thus comes within the general scope of the statistical method.[18]

STATISTICS IN EVERYDAY LIFE

46. The importance of statistics in the field of science is due to its supplying the general method for inductive inference. The growing importance of statistics in public estimation, on the other hand, is mainly due to its increasing practical applications in the affairs of everyday life. It is necessary to remember that at one time physical science itself was held in low esteem in the public eye, and was often a subject of contempt and ridicule. It is interesting to observe that Thomas Sprat made the following observations in 1667, five years after the foundation of the Royal Society of London:

> "It is not to be wonder'd at if men have not been very zealous about those studies, which have been so far removed from present benefit, and from the applause of men. For what should incite them to bestow their time, and Art, in revealing to mankind, those Mysteries; for which, it may be, they would be onely despis'd at last? How few must there needs be, who will be willing, to be impoverish'd for the common good? While they shall see, all the rewards, which might give life to their Industry, passing by them, and bestow'd on the deserts of easier studies?[19]

It is only with the great technological achievements of physical science that public opinion changed in a remarkable manner, and it rose in public esteem. It is this public esteem which enabled the physical scientists to secure sufficient leisure, support, and recognition to pursue their researches free from care and anxiety. This also led to the growth of the belief that scientific research is pure in the degree in which it is removed from practical applications.

'PURE' AND 'APPLIED' SCIENCE

47. I am prepared to admit that a distinction may perhaps be made between 'pure' and 'applied' science. A subject like physics, for example, has a clear responsibility for developing a picture of the universe in terms of physical concepts and elements even if this picture has no practical applications. This is also true of other 'pure' sciences like chemistry, botany, zoology or geology; each has the task of supplying a world-picture in its own terms. In an applied science like engineering, the position is quite different. It has no responsibility (nor any possibility) of giving a general theory of the world in terms of engineering. Its only task is to solve a practical problem. It must, of course, undertake research in its own field. As regards mathematics, it is simply not possible to have too much help from that subject, but there is no such thing as 'mathematical engineering'.

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[18] The work is, no doubt, closely connected with engineering or technological and scientific invetigations so that the position is somewhat similar to the field of statistical quality control.

[19] *History of the Royal Society*, London, 1667, p. 27.

STATISTICS—ESSENTIALLY AN APPLIED SCIENCE

48. In the same way, statistics is essentially an applied science. Its only justification lies in the help it can give in solving a problem. Its aim is to reach a decision, on a probabilistic basis, on available evidence. If the problem is one of a theoretical nature, statistics supplies a valid method for drawing general conclusions from particular experience. If the problem is a practical one, statistics supplies the basis for choosing a particular course of action (in preference to other possible courses) by balancing the risks of gain and loss. This is why Clark Maxwell once remarked that "the true logic for the world is the calculus of probability."

49. On the above view, we can not contemplate any cleavage between the thoery and the practice of statistics. On one side, statistics must necessarily be tied closely to practical ends. On the other, it must try at the same time to mke its technical apparatus more and more general, and hence more and more abstracted from particular applications. Statistics, like engineering, requires all the help it can receive from mathematics; but statistical theory can never become a branch of mathematics. Individual workers would specialize in particular fields in accordance with their own preference. Some would apply their mind closely to practical applications; some to the development of the mathematical technique; and others to the formulation of logical concepts and abstract theory. The number of persons working in the difierent fields would be naturally determined, partly by the demand for particular types of work (applications, or mathematical technique, or logical concepts and foundations) and partly by the supply of men of the required aptitude and ability. The integration of practical applications with mathematical and theoretical studies, which is the characteristic feature of modern statistics, is perhaps a good model for other sciences also. If technology is divorced from scientific research, it would soon loose its efficiency and adaptability to meet changing requirements. On the other hand, if research is cut off from the stimulus to solve vital problems of human society, it would beceme lost in sterile intellecutual acrobatics.

THE SOCIAL BACKGROUND OF STATISTICS

50. In statistical research the greatest stimulus has always come from the need of solving practical problems. R. A. Fisher's work on the design of experiments was due to the urgent need of solving the deadlock in agricultural field trials. W. A. Shewhart's work on quality control arose from the need of improving the efficiency of inspection in large scale production. On the organizational side also, statistical work is closely determined by the special needs of the country and by the socio-economic frame-work. Statistics is not only an applied science but is also a public science. It is because of the close connexion with public activities that big developments in statistics have always occurred only when there has been need of unified policy and co-ordinated action in times of war or peace. I shall give three examples.

51. For a long time the volume of statistical work has been greater in the United States than in any other country of the world. But it was only during the New Deal in the 1930's when unified governmental policy became indispensable in the economic field, that effective action was first taken for the central co-ordination of the statistical activities of the Federal Government. Other large developments took place because of the need of planning in war production; and it was only in 1942 that an Act

was passed to assign definite statutory responsibilities to the special Division of Statistical Standards in the executive office of the President of the United States.

52. In the United Kingdom also, under *laissez faire,* statistics had been developing in a more or less haphazard manner without any focal centre within the governmental machinery. All this, however, changed rapidly owing to the need of total planning during the war. A Central Statistical Organization was set up and was entrusted with the duty of reviewing and making a critical appreciation of all statistical information required by the Cabinet. Although the different Ministries have their own statistical divisions, there is complete co-ordination at the top. After the war, the importance of the Central Statistical Organization has continued to increase with the growth of social and economic planning in the United Kingdom.

53. In the U.S.S.R., developments in the statistical field have gone much further. From the beginning a Central Statistical Bureau has been an integral part of the GOSPLAN. No plan can be put into operation until it is cleared by the Statistical Bureau. The Bureau not only helps in preparing the different plans, but also submits reports on the progress of such plans on the basis of the information collected directly by the Bureau. In 1947 it had in fact a staff of 22,000 scattered all over Russia and paid and controlled directly by the Bureau. Central control by statistical methods is thus complete in the U.S.S.R.[20]

54. In India also there was a great deal of expansion in statistical work during the war without, however, any central co-ordination. Such lack of co-ordination was inevitable in the absence of any coherent over-all economic policy. Until the Government of the country has an urgent sense of the need of statistical services in shaping policy and programme of action, little progress is possible. In spite of much talk, no action was taken for central co-ordination in India until very recently. There was indifference and even hostility to new ideas and new developments. This is typical of the struggle through which scientific innovations must pass in order to establish their worth. I may illustrate these points by briefly recapitulating the story of sample-surveys in India.

SAMPLE-SURVEYS IN BENGAL

55. For a long time, crop statistics was known to be unreliable in Bengal. In 1934 I discussed with Mr. H. P. V. Townend, I.C.S., (then Development Commissioner, Bengal) the possibility of using random samples for the improvement of the Jute forecast. On his initiative, a sample-survey on an area basis was conducted over the whole province in 1935. I believe this was the first area-sample in the whole world.[21] The results were not satisfactory; chiefly, I thought, because of defective field work. A little

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[20] It is interesting to note that about a year ago, the Central Statistical Bureau was removed from the GOSPLAN and was placed directly under the Council of Ministers (which corresponds to the Cabinet in India). This would seem to indicate that the Bureau now has the further responsibility of submitting reports on the GOSPLAN itself.

[21] As far as I know, Sir John Hubback was the first person to consider random sampling for estimating crop areas; but he did not use it in practice. His own work was concentrated on statistical sampling for the yield of rice in Bihar and Orissa in the early 1920's. His original report "Sampling for Rice Yield in Bihar and Orissa" published in 1927 as Bulletin No. 166 by the Agricultural Research Institute, Pusa, was reprinted it *Sankhyā*: the Indian Journal of Statistics, Vol. 7, Pt. 3.

later, the Indian Central Jute Committee approved a five-year scheme for a sampling method for the jute crop. Work was started, on a very small scale, in 1937, and an efficient sampling plan was developed by the Indian Statistical Institute by a series of annual surveys, on a gradually expanding scale, until the whole province was covered in 1941.

56. Three tests had been laid down for the sampling plan which were adequately fulfilled. The method was speedy, inexpensive, and the margin of uncertainty of the provincial estimate was only about 2 per cent[22]. Influential opinion was, however, still strongly opposed to the scheme, and it was terminated at the end of 1941. Since then it has passed through many vicissitudes. The sample-survey was revived in 1942 for only one year. Since 1939 I had been pressing Government to have the sampling plan extended to rice. In view of the cessation of the supply of rice from Burma, which by this time had fallen to the Japanese, I sent to a high agricultural official in New Delhi in March 1942 a plan for a sample-survey of rice in Bengal; my letter was not acknowledged. In 1943 a famine broke out in Bengal and caused the death of a million-and-a-quarter or a million-and-a-half of men, women, and children. The sample-survey was started afresh in April 1943; was stopped after two months, in June; and was again started in August and extended to the rice crop for the first time, owing chiefly to the urgent need of food statistics.

57. The adequacy and reliability of the sample-survey was challenged on every occasion. In fact, a sample-survey of crops which had been started in Bihar in 1943-44 was discontinued after one year on the advice of the Agriculture Department of the Government of India, in spite of my earnest pleadings in personal discussions, and in a letter which I sent to New Delhi on the 23rd March 1945. In Bengal also, the position was precarious in 1944. However, after many debates and discussions, the Government of Bengal decided to continue the sample survey, and also to organize a plot-to-plot enumeration with a view to comparing the two methods.

COMPARISON OF SAMPLE SURVEY AND PLOT-TO-PLOT ENUMERATION IN BENGAL : 1944-45

58. In accordance with the above decision, a plot-to-plot enumeration was conducted directly by the Government of Bengal in the winter (*aman*) rice season of 1944 and the jute season of 1945; while the sample survey was conducted by the Indian Statistical Institute. The sample survey was, of course, much more economical. The total cost of the plot-to-plot enumeration was about Rs. 82 lakhs (about £61,500 sterling) while the cost of the sample survey was Rs. 8 lakhs only, or just one-tenth. The intensity of sampling was unusually heavy, owing to the desire of Government to have separate figures for 28 smaller geographical units (districts). For a provincial total, or for 3 or 4 regional breakdowns, the cost of the sample survey could have been easily reduced to Rs. 6 lakhs or even Rs. 4 lakhs. From the experience of about 12 years of work in Bengal, we have found that a sample-survey of crops can supply results of sufficient accuracy

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[22] A full account of the work up to 1941 was given in the paper "On Large Scale Sample Surveys", *Phil. Trans. Royal Society of London*, Vol. B. 231, (1944), 329–451; some later work has been described in "Recent Experimets in Statistical Sampling in the Indian Statistical Institute". *Jour. Royal Statistical Society*, CIX (4), 1946, 325–378.

for most practical purposes at a cost of only a fifteenth or a twentieth of that of a complete count.

59. It is, however, in the matter of precision that the sample survey has the greatest advantage. It is possible to make a direct comparison for the jute crop of 1945 in Bengal. Jute being primarily a cash crop, accurate export and trade figures become available about 15 months after the harvesting season. The sample-survey estimate, submitted to Government in September 1945, was 7,540 bales of jute.[23] The official forecast in the same month, based on the plot-to-plot enumeration, was 6,304 bales. According to the customs and trade figures which became available in January 1947, the Bengal production was 7,562 bales. The plot-to-plot enumeration gave an under-estimation of 16.6 per cent, while the sample-survey figure differed by only 0.3 per cent from the estimate based on trade figures. Details of the comparison are given in Appendix (4). *The plot-to-plot envmeration was ten times more expensive, and yet gave entirely inaccurate results.*

60. The reason for the greater reliability of the sample-survey is clear. The total staff employed in the plot-to-plot enumeration was about 33,000 against roughly about 600 or 700 in the sample-survey. Sample-surveys require a much smaller staff. It is, therefore, always possible to employ better trained people on higher pay, and also to maintain close supervision on their work. In consequence, the primary material in sample-surveys is usually of much better quality, and furnish final estimates of greater accuracy.

61. In Bengal, the superiority of the sample-survey was finally acknowledged in January 1948, when the sample-estimates were ordered by the Government of the Province to be accepted in future as official crop-estimates. It had taken eleven years (since 1937) to achieve this result.

62. A good deal of similar evidence has accumulated in other countries of the world. I shall refer to some very recent work in Japan. At the request of the Occupation Authority, the Japanese Government conducted in 1948 a plot-to-plot enumeration of crops (on the basis of old cadastral survey records) of the whole country. Sample-surveys were superposed to assess the accuracy of the plot-to-plot enumeration. The sampling work was done with great care, in fact, with plane table operations with the help of surveying instruments. The combined under-estimation (due to both non-reporting of fields, and under-statement of crop area reported) was about 9.5 per cent for paddy rice, 20 per cent for mixed cereals, more than 26 per cent for sweet potatoes and fully 35 per cent for upland rice.[24]

RECENT CHANGES IN ATTITUDE

63. In recent years the sampling method has won increasing recognition all over the world. In 1947 the United Nations established a Sub-Commission on Statistical Sampling which has already met three times in 1947, 1948 and 1949, and has issued three reports covering a very wide field. In India also there has been a distinct change of attitude. The

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[23] 1 bale = 400 lbs. of jute.

[24] United Nations document E/CN.3/Sub.1/17. Appendix C, pp. 27-32 ; and also an article on the "Incompleteness in a Census of Crop Areas in Japan" by Charles F. Sarle in *Agricultural Economics Research*, April 1949 (published by the United States Department of Agriculture).

Government of India are seriously considering the possibility of using sampling methods in the field of agricultural statistics. This has been brought about partly no doubt by the increasing prestige of the method outside India. But it is also symptomatic of a deeper change. The Government of India are giving increasing attention to the all round improvement of the statistical services of the country. This in its turn is due to a growing awareness of the urgent need of unified economic policy and action on the part of Government. It is the urge of solving vital national problems which is giving real strength to the progress of statistics in India. I shall now turn to some of these problems.

THE FOOD CRISIS IN INDIA

64. The biggest single problem in India at present is the shortage of food supply. On the 28th November 1949, Jawaharlal Nehru, the Prime Minister of India, is reported to have declared "I desire to make it perfectly clear that whatever happens, whether there is a cyclone or an earthquake, we are determined to stick to the target date of 1951, after which we shall not import food grains for our consumption." He stated that this decision had been forced on the country by the pressure of events, for no country could continue to live beyond its means which of course meant its production in its fields or its factories.

65. I shall try to give a statistical commentary on the Prime Minister's statement. This will serve two purposes. It will show how statistics comes into the picture, and how statistics can help in solving the problem. It will also show how inadequate is the available statistical information, and how much it requires to be improved. The figures quoted by me are, therefore, necessarily illustrative.

INCREASING PRESSURE OF POPULATION

66. The food position can be judged only in relation to population and other resources of the country. We know the total geographical area of the Indian Union. It is about 1.22 million sq. miles or 780 million acres.[25] As regards the population, the last decennial census was taken in February 1941. Since then conditions have been abnormal owing to war, the famine in Bengal in 1943, and the partition in August 1947 with subsequent large shifts of population. On the available information, the total population at present would seem to be something between 34 and 35 crores (340 and 350 millions).

67. The density of population is thus very high, something like 290 per square mile, which is bigger than the density in most countries of the world with the exception of the highly industrialized countries in Western Europe, and Japan. If we consider the individual share, in India we have only about 2.25 acres per head.[26] In comparison, China presumably has about 6 acres, the United States about 13 acres, and the U.S.S.R. nearly 28 acres for each individual. The pressure on land is many times greater in India compared to other countries with a large population.

68. The population is also increasing at a rapid rate. Between 1931 and 1941 the rate of increase was about 1.4 per cent for the

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[25] 3.159 million sq. kilometers.

[26] The total area under cultivation in India is not known accurately. It is probably something like 35 or 40 per cent of the whole area. The share of cultivated land is thus well below one acre per head,

Indian Union.[27] If this rate is being maintained, the population of India is increasing at present by nearly five millions every year. This is more than the total population in each of about 24 or 25 member States of the United Nations. Owing to the adverse conditions created by the war and the partition of India, the rate of growth may have slowed down. If it is only 1 per cent, the increase is still something like 3.5 millions per year.[28]

INADEQUACY OF FOOD STATISTICS

69. About population we have some information. The position is much worse about food statistics. In one province, West Bengal (covering only about 2.5 per cent of the total area of India), statistical sampling is being used and can be depended upon to supply estimates of the production of rice with a margin of uncertainty of about 2 per cent. For roughly half the total area of India, reports are available from *patwaries* (village revenue staff) or *chowkidars* (village watchmen) but nothing is known about their accuracy as no objective checks have been made. In roughly one-fifth of the whole area, reports are received from the State authorities, but nothing is known about the primary agency. No reports whatsoever are available about the food production for the remaining 30 per cent of Indian Union, and a conventional figure is written down every year in New Delhi. In spite of the Grow More Food campaign conducted for several years, according to official estimates of the Ministry of Agriculture, apparently no appreciable increase has occurred in the production of food. It is best to confess that we do not know the real position.

CRITICAL BALANCE BETWEEN FOOD AND POPULATION

70. There is some indirect evidence. Actuarial estimates on the basis of the decennial censuses between 1881 and 1931[29] show that there has not been any appreciable increase in the expectation of life at birth which hovered round or below 25 years during this period. This suggests that, although population increased at a rapid rate, there was no over-all improvement of the vitality of the people.

71. The famine in Bengal in 1943 was also an ominous indication. From the information collected by the Indian Statistical Institute in the course of a sample survey of famine conditions, I believe the total number of deaths was something between one-and-a-quarter and one-and-a-half million. The total loss (killed and missing) in the second world war was about 330,000 for the U.S.A., and 300,000 for the United Kingdom.[30] Thus the famine casualty in Bengal was double or more than double of the total war casualty for the U.S.A. and the U.K. taken together. It may be noted that in 1943, the area of the undivided province of Bengal was about 78,000 sq. miles, and the estimated population about 63 millions. The density was thus of the order of 800 per sq. mile, which was higher than

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[27] *Census of India Paper No.* 2, p. 6 (Government of India). The rate of growth during the same period in undivided India was 1.5 per cent per year.

[28] During the 40 years between 1901-1941, the average rate of increase was about 1 per cent per year in undivided India and over 0.8 per cent per year in the Indian Union. Even at this lower rate, the increase would be about 3 millions per year.

[29] No information is available for the 1941 census, as age-tables were not prepared. These are, however, now being constructed in the Indian Statistical Institute on the basis of the 2 per cent Y-sample.

[30] *Encyclopaedia Britannica : Book of the Year*, 1946, p. 846.

that in even the most highly industrialized countries of the world. The terrible pressure of population was no doubt a predisposing factor in the famine[31].

INCREASING FOOD IMPORTS

72. Some further indirect information is available from export and import statistics. Before the separation in 1937, Burma provided an abundant supply of rice. During the first two or three years of the war, the net import was negligible as the following figures will show.

NET IMPORT OF CEREALS PER PERSON

financial year	extrapolated population in millions	net import of cereals in million tons	import in lbs per year per person
(1)	(2)	(3)	(4)
1941–42	390.3	0.43	+ 2.5
1942–43	395.4	–0.29	– 1.6
1943–44	400.4	0.33	+ 1.8
1944–45	405.5	0.73	+ 4.0
1945–46	410.6	0.93	+ 5.1
1946–47	415.7	2.42	+12.9
1947–48	335.2	2.18	+14.6
1948–49	337.9	2.78	+18.4

(1) Population figures for undivided India were calculated by linear extrapolation with the observed growth rate between 1931 and 1941. Figures after partition (15 August 1947) are based on the *Census of India, Paper No. 2.*

(2) Up to 1942-43, net imports in col. (3) are taken from the *Food Statistics of India* (1946) published by the Food Department; from 1943-44, the figures are taken from *Indian Food Statistics* (August 1949) published by the Ministry of Agriculture. Since 1943-44 the figures relate to rice, wheat, maize, millet, barley and wheat flour, with a few minor variations.

73. In 1943-44, the year of the Bengal famine and the first year of introduction of food rationing, the net import was quite small and only about 1.8 lbs. per head per year. During the last five or six years, the position has grown steadily worse. The net import rose to about 18 lbs. per head in 1948-49, and the expenditure incurred was something like Rs. 120 or 130 crores (about £100 million sterling). The significance of this figure can be appreciated when it is recalled that the total revenue budget of the Government of India in 1949-50 is of the order of Rs.320 crores (£240 million sterling).

74. Another aspect of the problem is even more serious. If the food production and the home consumption remain constant, then the surplus coming to the market would also remain constant. In this situation, the total import should increase in proportion to the growth of population. In actual fact the import rose from 0.33 million tons in 1943-44 to 2.78 million tons in 1948-49. The was, no doubt, partly due to the cessation of supplies from Pakistan which was a surplus area. In any case, the supply coming into the market (through procurement or otherwise) has been steadily decreasing. This is the most alarming feature of the present situation.

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[31] "A Sample-Survey of After-Effects of the Bengal Famine of 1943". *Sankhya: The Indian Joural of Statistics.* Vol. 7 (4), 1946. pp. 337-400.

STATISTICAL BASIS OF A RATIONAL FOOD POLICY

75. What is the solution? There is obviously no single remedy. The problem has to be attacked on many fronts, and statistics can help on all fronts. I shall briefly try to indicate the magnitude of the task. First, every effort must be made to increase the crop production. Fertilisers, improved seeds, irrigation, and better methods of cultivation are already being used and must be pushed much further. Experimentation at the research level in agricultural field trials must be continued and developed with closer gearing to actual conditions of cultivation. Another possibility is the improvement of varieties through fundamental research in genetics. The spectacular increase in the yield of maize in the U.S.A. is a striking example of the success of such researches. Rice offers a promising field for similar work, and an increase of 25 per cent or 30 per cent in the yield is a definite possibility. Well-equipped centres for the study of rice genetics should be, obviously, established without delay. Here statistics can render effective help. In fact, in the field of agricultural experimentation and genetics, powerful methods like the design of experiments, the analysis of variance, and the theory of estimation are already available.

INCREASING DIFFICULTIES IN THE FUTURE

76. It is certainly necessary to attain self-sufficiency in food in 1951. But this is not enough. The production of food must keep pace with the growth of population. But not only food, it is also necessary to produce new houses, clothes, and thousands of other things in increasing quantities. Production must keep pace with population. The future trend of population in India is, therefore, a matter for serious concern. Available evidence indicates that at the existing level of production, the balance has already become adverse. A further and continual growth of population without a commensurate growth in the means of production will be disastrous. The only way is to develop our national resources.

INDUSTRIAL DEVELOPMENT

77. Rapid industrial development is one possibility. Government have already started work on a number of big multi-purpose dams for both irrigation and power. A beginning has also been made with machine tools and other basic industries and heavy chemicals. The building of houses, electricals, and other innumerable industries (including production of consumer goods) must be stepped up. All this would require capital goods in the way of plant and equipment, land and buildings, and labour.

78. It will be useful to obtain even a very rough idea of the capital requirement. The ratio of the gross value of the annual product to the capital investment varies widely from one industry to another. The ratio would be small in the case of iron and steel or basic industries; the gross value of the annual product may be something like one-third, or one-fourth, or even one-fifth of the invested capital. In electricals and lighter industries the ratio may be unity or even higher. Unfortunately very little information is available.[32] At a rough guess, the over-all value of the ratio is likely to be something between half and unity.

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[32] It may be noted that the over-all ratio of the annual value of the product to the invested capital is about 1.6 in the case of the industries covered by the Industrial Census of 1946 (Ministry of Industry and Supply). It must be remembered, however, that most of the capital investment took place long ago, while the annual product was valued at 1946 prices. If the value of the plant, machinery, and building is re-calculated at 1946 or current prices, the total amount of capital investment would be much higher than that actual shown in the returns. That is, the ratio would certainly fall much below 1.6.

79. It is also necessary to take into consideration what the economists call the 'multiplier' effect. To put it crudely, the multiplier stands for the additional value of products, and business and other activities stimulated by the increase in the primary product. (For example, an increase in the production of steel and cement may be expected to lead to an increase in the building of houses and construction work and other industries in an indirect way). No information is available about the value of the 'multiplier' in India. It is sometimes guessed that the multiplier may be something like 1.5 or so. To get a dimensional figure, we may perhaps assume that an investment of, say, one crore of rupees would lead to an increase of an equal amount in the national product (inclusive of the 'multiplier' effect). The actual ratio may be somewhat higher or somewhat lower, but this would give a rough dimensional picture.[33]

80. Consider the implications. To increase the value of the national product by one rupee per head per month or, say, twelve rupees per head per year, it is necessary to invest 420 crores of rupees (=Rs. 12 × 35 crores) or £310 million sterling. Compare this figure with the budget of the Government of India which is something like Rs. 320 crores (£240 million sterling) in 1949-50. Even if this whole amount is used for industrial development, the value of the national product is not likely to increase by more than, say, twelve annas or a rupee per head per month. It is clear that the Government of India alone can do very little. The industrial development of India depends entirely on the efforts which the people of the country are prepared to make.

THE NATIONAL INCOME

81. The next question which arises is the extent to which the people can afford to contribute to industrial development. Investing one rupee would bring a return of one rupee in future years; but whether one can afford to invest even one rupee depends on his income. This brings us to the question of the national income of India. Little reliable information is available.[34] Again one can only guess. Perhaps, the monthly income is Rs. 12/- or may be. Rs. 15/- per head. We do not know, but this may be the right order. We have also the other guess of 'a rupee for a rupee,' that is, a future national product of one rupee for a present investment of one rupee. The choice is definitely between jam today and jam tomorrow. We cannot have both. Indeed, unless we save and invest for the future, we may have less and less in future.

THE STATISTICAL POSITION

82. With meagre material I have constructed a dimensional picture which is admittedly very rough. It will have served its purpose, if it has conveyed to you some idea about the magnitude of the task in front of us. Secondly, if it has made you feel the urgent need of having more and better statistics. Along with the efforts to increase food production, attempts must be made to improve the statistics not only of the production of food but of its consumption and distribution. A gap of 10 years between population censuses is no longer tolerable. It is necessary that we should

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[33] It is assumed, of course, that the new capital investment is not in competition with existing investment, that is, does not divert any of the factors of production firm existing modes of production.

[34] Pioneer work was done by Dr. V. K. R. V. Rao who gave in 1940 an estimate of the natonal income for1931-32; and in 1944 gave a tentative estimate for 1942-43. No authoritative estimates for recent years are yet available.

have information about the growth of population every year. We require information about the distribution of income and expenditure in different sectors of national economy, and in different strata of the population. We must, in fact, set about earnestly to develop a comprehensive system of social accounting for the whole nation.

83. Of capital requirements I have given a sombre picture. In one sense it is, however, not as dark as it looks at first sight. The capital investment is broadly of three kinds. First, machinery and equipment (and technical personnel) which we must import from abroad and must pay for ultimately in hard cash. Secondly, land and water, minerals, forests, livestock and animals, which we have in the country; and also buildings and material equipment which we have or which we can produce in India. And finally, man-power and labour which we have in abundance. In the beginning, the share of imported equipment from abroad must be necessarily heavy; but as the basic industries develop, this item should become smaller and smaller. The other two items, man-power and material resources, are our own. The imputed value entering into the capital account is, in a real sense, a matter of book-keeping. We can make what we like of these items. If the people and the Government are united in one common endeavour, then the human labour and the material resources in the country are completely at our disposal for national development.

84. If the statistical picture I have placed before you is not hopelessly wrong, then we are in difficult times and are probably facing greater difficulties than we have ever done in the past. The united effort of the Government with the people can save us. Such united effort can be brought about only by concerted action. To prevent waste of money, effort, resources, and most critical of all, to prevent, any further waste of time, planning on a national scale is essential.

NATIONAL PLANNING

85. National planning has several aspects. First, there is the preparation of plans at the technical level requiring the help and cooperation of workers in every branch of science and technology. Statistics is indispensible at this stage for the supply of basic information. Secondly, the individual plans have to be built into a general plan. Here statistics is the common denominator, and supplies the common binding medium for the whole. Thirdly, the plan has to be implemented. At this stage also, statistics can help in two ways. Firstly, by establishing scientific controls to ensure that the programme of action proceeds on efficient lines. Secondly, by conducting continuous assessments of the results by keeping account of the input of money, effort, and resources, and measuring what is obtained in return. The process is never-ending. In the actual working of the plan, defects are revealed, and new possibilities emerge requring consequential changes. Statistics is again invaluable in diagnosing weaknesses, in guiding controlled experiments, and in suggesting improvements. Statistics is thus pivotal in the dynamics of national planning. I hope you have now received a proper answer to the question: Why statistics?

RECENT DEVELOPMENTS IN INDIA

86. As I have already indicated, the progress of statistics must, depend upon and is closely determined by socio-economic trends. In India, we have seen during the last one year, hopeful signs of advance. A

Standing Committee of Departmental Statistics with representatives from the different Ministries of the Government of India was established in October 1948. A Central Statistical Unit was created, under the charge of a Statistical Adviser to the Cabinet, on the 28th January 1949. For the first time, a permanent office for the Census and Vital Statistics was established under a Registrar-General and ex-officio Census Commissioner in May 1949. A first comprehensive report on the industrial census of 1946 was published in July 1949. A National Income Committee was set up in August to review the position in this field and to make such estimates as may be possible. And the Central Statistical Unit was converted into a Central Statistical Organization on the 21st December 1949. All this indicates a move towards a more comprehensive review and formulation of the economic policy of the country. We may also hope to reach again, of course, in a more modern form, the state of development in statistics which was reached in India in the days of the survey of Eastern India in early 19th century, in the days of Akbar at the close of the 16th century, or in the days of Asoka in the third century B.C..

THE CHOICE BEFORE US

87. Our vast population is a great asset, but only in a potential form. In India we have every year a vast quantity of water in the form of rainfall. Most of it is wasted. Sometimes, in times of flood, it becomes a menace. But, by building dams and hydrels we can put it to work, and make it a source of power for fruitful production. In the same way, our vast man-power is at present lying mostly stagnant. A great deal remains idle, and a great deal is wasted in inefficient production. Perhaps it is wise to remember that, out of control, it may also become a menace fraught with grave dangers of self-destruction. But, if we can harness this living reservoir of power, there is nothing which we cannot accomplish.

88. So far attempts have been made to hire this power in a market place. We should think seriously whether we have the means, or the time, to continue to do so. Conditions are changing rapidly. It is a matter for serious thought whether or not the wiser policy would be to rally the common man into a great effort for national welfare. We look to our political leaders for guidance, decision, and action.

89. In a national plan, scientists and technologists also have to make their contributions. They can give the labour of their thought, and by the skill of their research and experimentation, show how to overcome difficulties and open out new possibilities. The statisticians have a humble role, but they also can help in reaching vital decisions. To this great ask I call all my friends and colleagues.

APPENDIX 1

SURVEY OF EASTERN INDIA : 1807-1815

[The following extracts are taken from the Introduction to "The History, Antiquities, Topography, and Statistics of Eastern India" by Montgomery Martin, London, 1838.]

The Survey of the districts of Behar and Patna, of Shahabad, Bhagulpoor, Dinajepoor, Goruckpoor, Puraniya, Rungpoor, and Assam, forming the Eastern territories of British India, and containing upwards of 60,000 square miles and nearly 15,000,000 of British subjects, was executed by the Supreme Government of Bengal, under orders from the Court of Directors of the Honourable East India Company, dated the 7th of January, 1807, wherein the Honourable Court observe, "We are of opinion that a statistical survey of the country, under the immediate authority of your Presidency, would be attended with much utility; we therefore recommend proper steps to be taken for carrying the same into execution."

The extent of the investigation will be seen from the directions issued for the guidance of the survey by the Supreme Government under date 11th Sept. which were as follows :—

"Your inquiries are to extend throughout the whole of the territories subject to the immediate authority of the Presidency of Fort William.

"The Governor General in Council is of opinion that these inquiries should commence in the district of Rungpur, and that from thence you should proceed to the westward through each district on the north side of the Ganges, until you reach the western boundary of the Honourable Company's provinces. You will then proceed towards the south and east, until you have examined all the districts on the south side of the great river, and afterwards proceed to Dacca, and the other districts towards the eastern frontier.

"Your inquiries should be particularly directed to the following subjects, which you are to examine with as much accuracy as local circumstances will admit.

'I. A Topographical account of district, including the extent, soil, plains, mountains, rivers, harbours, towns, and subdivisions : together with an account of the air and weather, and whatever you may discover worthy of remark concerning the history and antiquities of the country.

"II. The Condition of the Inhabitants; their number, the state of their food, clothing and habitations ; the peculiar diseases to which they are liable ; together with the means that have been taken or may be proposed to remove them ; the education of youth ; and the provision or resources for the indigent.

'III. Religion ; the number, progress and most remarkable customs of each different sect or tribe of which the population consists ; together with the emoluments and power which their priests and chiefs enjoy ; and what circumstances exist or may probably arise that might attach them to Government, or render them disaffected.

'IV. The Natural Productions of the Country, animal, vegetable, and mineral ; especially such as are made use of in diet, in medicine, in commerce, or in arts and manufactures. The following works deserve your particular attention :

'1st. The fisheries, their extent, the manner in which they are conducted, and the obstacles that appear to exist against their improvement and extension.

'2nd. The forests, of which you will endeavour to ascertain the extent and situation, with respect to water conveyance. You will investigate the kinds of trees which they contain, together with their comparative value and you will, point out such means, as occur to you, for increasing the number of the more valuable kinds, or for introducing new ones that may be still more useful.

"3rd. The mine and quarries are objects of particular concern. You will investigate their produce, the manner of working them, and the state of the people employed.

"V. Agriculture, under which head your inquiries are to be directed to the following points :

"Ist. The different kinds of vegetables cultivated, whether for food, forage, medicine, or intoxication, or as raw materials for the arts : the modes of cultivation adopted for each kind ; the seasons when they are sown and reaped ; the value of the produce of a given extent of land cultivated with each kind. The profit arising to the cultivator from each, and the manner in which each is prepared and fitted for market. Should it appear that any new object of cultivation could be introduced with advantage you will suggest the means by which its introduction may be encouraged.

'2nd The implements of husbandry employed with the defects and advantages of each, and suggestions for the introduction of new ones, that may be more effectual.

"3rd. The manure employed for the soil, especially the means used for irrigation.

"4th. The means used for excluding floods and inundations, with such remarks as may occur to you on the defects in their management.

"5th. The different breeds of the cattle, poultry, and other domestic animals reared by the natives. The manner in which they are bred and kept the profits derived from rearing and maintaining them ; the kinds used in labour ; whether the produce of the country be sufficient, without importation, to answer the demand, or to enable the farmer to export ; and whether any kinds not now reared might be advantageously introduced.

"6th. Fences the various kinds that are used, and that might be introduced, with observations concerning the utility of this part of agriculture in the present state of the country.

"7th. The state of farms ; their usual size, the stock required, with the manner in which it is procured ; the expense of management the rent, whether paid in specie or in kind ; the wages and condition of farming servants and labourers employed in husbandry ; tenures by which farms are held, with their comparative advantages, and the means which, in your opinion, may be employed to extend and improve the cultivation of the country.

"8th. The state of the landed property and of the tenures by which it is held in so far as these seem to affect agriculture.

"VI. The progress made by the natives in the fine arts in the common arts and the state of the manufactures ; you will describe their architecture sculpture and paintings and inquire into the different processes and machinery used by their workmen and procure an account of the various kinds and amount of goods manufactured in each district. It should also be an object of your attention to ascertain the ability of the country to produce the raw materials used in them ; and what proportion, if any is necessary to be imported from other countries and under what adnvantages or disadvantages such importation now is, or might be made ; you will also ascertain how the necessary capital is procured, the situation of the artists and manufactures, the mode of providing their goods the usual rates of their labour ; any particular advantages they may enjoy, their comparative affluence with respect to the cultivators of the land, their domestic usages, the nature of their sales, and the regulations respecting their markets. Should it appear to you that any new art or manufacture might be introduced with advantage into any district, you are to point out in what manner you think it may be accomplished.

"VII. Commerce ; the quantity of goods exported and imported in each district the manner of conducting sales, especially at fairs and markets ; the regulation of money, weights, and measures ; the nature of the conveyance of goods by land and water and the means by which this may be facilitated, especially by making or repariing roads.

"In addition to the foregoing objects of inquiry, you will take opportunity of forwarding to the Company's Botanical Garden at this presidency, whatever useful or rare and curious plants and seeds you may be enabled to acquire in the progress of your researches with such observations as may be necessary for their culture."

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APPENDIX 2

THE IDEA OF DETERMINATE KNOWLDGE IN ANCIENT INDIA

[The following is reproduced from the Editorial, *Sankhyā*, Vol. 1, Part 1 (June 1933), pp. 3-4.]

We are convinced that statistics represents a fundamental method of analysis of data in the mass which is applicable to any science of observation, and we feel that it is desirable to emphasize this essential unity in the methodology of statistics.

We believe that the idea underlying this integral concept of statistics finds adequate expression in the ancient Indian word *Sankhyā*. In Sanskrit the usual meaning is 'number,' but the original root meaning was 'determinate knowledge'[1]. In the Atharva-Veda a derivative form *Sankhyātā* occurs both in the sense of 'well-known' as well as 'numbered.'[2] The Lexicons give both meanings. Amara-kosa gives *sankhyā* = *vicāranā* (deliberation, analysis) as well as 'number;' also *sankhyāvān* = *panditah* (wise, learned).[3]

The same dual sense is attached to its derivative form *Sānkhya*[4] which is the name of the most famous analytic philosophy of ancient India. The name of the philosophical system is explained in both ways: as a philosophy based essentially on enumeration of the categories beginning with Nature or Root Cause. Or else a philosophy by which is revealed the adequate knowledge of reality.[5] The root meaning is also met with in the Mahabharata in the Gitā[6] portion where the *Sānkhya* system of philosophy is classifed with the Vedanta as being based on *jnāna* (or intellectual cognition) as distinguished from the Yoga systems. Sridhara in his commentary on the Gitā explains *Sānkhya* as *samyag-jnāna*, that is 'proper cognition' or 'adequate knowledge.'

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[1] The word can be written *samkhyā* or in a simpler form as *sankhyā*, the sound of *anusvāra* (nasal glide following a vowel) assimilating with the following sound of *k* and becoming a velar nasal (like *ng* in English *sing*). The simpler spelling also indicates the current pronunciation (like *sungkhi-āh*).

The word is derived from *khyā* (to 'perceive, view' ; to be known,' 'to make well-known' 'n Monier Williams's Dictionary). The root meaning is 'determinate knowledge', 'deliberation' or 'whatever helps us in obtaining determinate knowledge' accordiog as the *kṛt* suffix is taken in the active or instrumental form. From the latter phase is derived the technical meaning of 'number'.

[2] Atharva-Veda, 4.25.2. It also occurs in 4.16.5 and 12.3.28.

Winterintz after a full discussion of the date of the Vedic age says "we shall probably have to date the beginning of this development about 2000 or 2500 B.C., and the end of it between 750 and 500 B.C." *History of Sanskrit Literature* (English Translation, Calcutta University, 1927), Vol. I, p. 310. While the present form of the Atharva-Veda is believed to be later than that of the Rg-Veda, much of its material is considered to be as old as, if not older than, many portions of the Rg-Veda. (Winternitz, p. 127). The word *sankhyā* is in common use in the sense of number in the time of *Panini*.

[3] Amara-koṣa, 1.4.2 (*dhīvarga*). '*carcā sankhyā vichāraṇā*' (deliberation, reasoning, investigation). Also 2.7.5. (*Brahmavarga*) "*sankhyāvān paṇḍitah.*"

Monier Williams gives 'number, numeration ; deliveration, reasoning, reflection ; reason, intellect, understanding' under *sankhyā*.

[4] If is interesting to observe that the *Sankhya* teaches differentiation between spirit (*puruṣa*) and matter (*prakṛti*). plurality of souls, independence eternity of matter, and explains creation as an evolutionary unfolding of the world from original matter. (Winternitz, p. 434).

The history of the word *sankhyā* shows the intimate connexion which has existed for more than 3000 years in the Indian mind between 'adequate knowledge' and 'number.' As we interpret it, the fundamental aim of statistics is to give determinate and adequate knowledge of reality with the help of numbers and numerical analysis. The ancient Indian word Sankhyā embodies the same idea, and this is why we have chosen this name for the Indian Journal of Statistics.

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[5] In Vacaspatya we have '*mūla-prakṛtyādi-padārthānām gananā*' ('the enumeration of the categories beginning with Nature, the Root Cause'). Monier Williams gives 'relating to number or calculation ; enumeration, deliberating, reasoning ; rational, discriminative' under *sankhyā*.

In the commentaries *Sānkhya* is usually derived as '*samyak khyāyate vastutatvam anayā* ('by which is reavealed fully the essence or truth of reality.')

Fitz-Edward Hall (*Sānkhya-Sara*, Bibliotheca Indica, and quotes on p. 3, Dr. Röer in support : "The term *Sānkhya* has two meanings, enumeration and investigation." (*Lecture on the Sānkhya Philosophy*, p.8).

The dual significance of the word *sānkhya* is the subject of a pun in the opening couplet of Bhāskarācārya's *Bīja-ganita*, the well-known treatise on Algebra.

[6] Bhagavad-Gītā, 2.39. It is usually placed in the early centuries A.D. (Winterntz, p. 438).

APPENDIX 3

THE DOCTRINE OF INFERENCE IN INDIA

[The following extracts are taken from Brajendranath Seal's "The Positive Sciences of the Ancient Hindus", 1915.]

The Doctrine of Inference : Anumāna (Inference) is the process of ascertaining, not by perception or direct observation, but through the instrumentality or medium of a mark, that a thing possesses a certain character. Inference is therefore based on the establishment of an invariable concomitance (*Vyapti*) between the mark and the character inferred. The Hindu Inference (Anumāna) is therefore neither merely formal nor merely material, but a combined Formal-Material Deductive-Inductive process- It is neither the Aristotelian Syllogism (Formal-Deductive process), nor Mill's Induction (Material-Inductive process). But the real inference which must combine formal validity with material truth, inductive generalization with deductive particularisation. (pp.250-251).

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The later Buddhists formulated the canon of a modified Method, termed the Panchakarani, a Joint Method of Difference, which combines the positive and the negative Methods of Difference (The Method of Addition and the Method of Subtraction) in a series of five steps, and which equally emphasises the unconditionality and the immediateness of the antecedents as essential moments of the causal relation. This is neither agreement in presence nor agreement in presence as well as absence (the foundation of J.S. Mill's Joint Method of Agreement), but the Joint Method of Difference. The Panchakarani runs thus:—

The following changes being observed, every thing else remaining constant, the relation of cause and effect is rigorously established:—

First step — The "cause" and the "effect" phenomenon are both unperceived.

Second step— Then the "cause" phenomenon is perceived.

Thrid step— Then, in immediate succession, the "effect" phenomenon is perceived.

Fourth step— Then the "effect" phenomenon is sublated or disappears.

Fifth step— Then in immediate succession, the"effect" phenomenon disappears. (pp.258-259)

APPENDIX 4

COMPARISON OF ESTIMATES OF JUTE ACREAGE IN BENGAL.

[The following note was prepared in 1947, at my request, by Dhirendra Mohan Ganguli then of the Indian Statistical Institute, Calcutta.]

	1944–45	1945–46
	(thousand bales)	
(1) Consumption during the season:		
(1.1) in jute mills (actual)	6,000	6,308
(1.2) exports (actual)	1,050	2,213
(1.3) in villages (estimate)	600	600
total	7,650	9,121
(2) Subtract quantity consumed from previous year's stock	— 324	— 697
(3) Subtract jute crop in other provinces	— 598	— 862
(4) Balance: Bengal crop from trade figures	6,728	7,562
(5) Bengal crop : official forecast (complete count)	4,895	6,304
(6) Bengal crop : sample-survey	6,480	7,540
(7) Discrepancy of official forecast on (4)	— 27.2%	— 16.6%
(8) Discrepancy of sample-survey on (4)	— 3.6%	— 0.3%

Source : Figures used in this table were taken from the *Final Review of the Jute Crop* (published by the Government of Bengal) ; and the *Monthly Summary of Jute and Gunny Statistics*, August 1946 and Jan. 1947 (issued by the Indian Jute Mills Association). One bale=400 lbs. of Jute.

NOTES ON CALCULATION (Paragraph numbers refer to serial numbers of items in the above table.)

(1.1) *Consumption in Jute Mills*: The Indian Central Jute Committee (ICJC), which is a statutory organization established by the Government of India, collects and publishes these figures every year. The Indian Jute Mills Association (IJMA) collects the figures from the member mills, and supply a consolidated statement to the ICJC. Mills outside the Association send their figures direct to ICJC. These figures are consolidated in the office of the ICJC, and two figures are published, one for the Association Mills and the other for the other Mills. The total is published in both the publications mentioned above, but as the *Final Review* was not published after 1946, the revised figures published by the IJMA were used in the present table.

(1.2) *Exports*: As exporters of raw jute have to pay a duty depending on the weight of jute exported, a very accurate account of the quantity of jute exported is kept by the Customs authorities. A daily list of exports showing quantities exported is published by the Customs authorities; and the consolidated annual figure is published in the "*Seaborne Trade of India*" by the Government of India.

(1.3) *Consumption in villages*: Several years ago this figure was fixed at 5 lakhs of bales by the IJMA. In 1941 a survey was conducted by the ICJC in collaboration with the Indian Statistical Institute to estimate the consumption in villages by a sample enquiry, and the figure was changed to 6,00,000 (6 lakhs) bales on the basis of the above enquiry. Both IJMA and the Government of Bengal accepted this figure, and used it in the two publications mentioned above.

(2) *Quantity consumed from previous year's stock*: The next step is to deduct the quantity consumed from previous year's stock from the total consumption during the year.

According to an Act passed by the Government of Bengal in 1941 all jute mills, jute balers, and jute dealers have to submit a return showing the stocks of jute with them on the 30th June every year. For several years there was a Special Officer (Jute) in the Government of Bengal, in whose office these figures were compiled. Actual figures were collected from the mills and balers and dealers of Calcutta and the neighbouring industrial area while estimates were prepared for the stocks held by muffasil dealers and growers on the basis of reports received from the District Agricultural staff.

Calculation of consumption from previous year's stock

	1944–46 (thousand bales)	1945–46
(2.1) Stock at the beginning of the season:		
(2.11) with IJMA mills	2,342	2,712
(2.12) with other mills	83	114
(2.13) with growers	466	150
(2.14) with muffasil dealers	816	475
(2.15) with Calcutta balers and dealers............	643	575
total (2.1) ...	4,350	4,026
(2.2) Stock at the end of the season:		
(2.21) with IJMA mills	2,712	2,604
(2.22) with other mills	114	105
(2.23) with growers	150	82
(2.24) with muffasil dealers	475	160
(2.25) with Calcutta balers and dealers	575	378
total (2.2) ...	4,026	3,329
Decrease in stock: (2.1) — (2.2) (consumption of old stock during the year)	324	697

(3) *Jute crop in other provinces*: This is estimated by the respective Provincial Directors of Agriculture. Plot-to-plot enumeration of the jute crop alone was undertaken in these provinces during the years 1939-43; and the subsequent estimates were prepared on the basis of the above plot-to-plot enumeration and local information obtained every year through the staff deputed for this work. The figures for Bihar include the crop from Nepal which finds its way to the Indian market through Bihar. The figures were taken from the *Final Jute Forecast*.

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SECTION OF MATHEMATICS

PRESIDENT : N. M. BASU, D.SC.

Presidential Address

MATHEMATICS AND MATHEMATICAL STUDIES IN FREE INDIA

I deeply appreciate the great honour that has been done to me in electing me to preside over the deliberations of the section of Mathematics of the current session of the Indian Science Congress. It is not merely a great honour,—it is also a rare privilege to have the opportunity of addressing such a galaxy of distinguished scientists who have assembled here from all parts of this country as well as from several foreign countries representing some of the most scientifically advanced nations of the world. I must however freely confess that I felt not a little perplexed when I pondered over the main obligation that I would be required to discharge, namely, that of preparing and delivering a Presidential address ; for, the choice of a suitable subject appeared to me somewhat difficult . The usual practice followed by past Presidents has been to select some highly specialised topic of Mathematics for their addresses and this has almost established a tradition, and it is no easy matter to break away from tradition. It was open to me to follow in their footsteps, but it seems to me,—and I have formed this impression from my personal experiences on many such occasions,—that at a gathering like this, which is likely to include, in addition to some mathematical luminaries, a large number of other scientists whose main interest is not mathematics and a fair number of young graduates and students as well, a talk on a very restricted field of the subject would not perhaps be very suitable, as such a talk would be rather highly technical and could be followed with interest by only a limited few while the large majority of the audience would find it dull and uninteresting. A general survey of the subject, on the other hand, covering the entire field, which would necessarily contain some things of interest to almost every one of the audience, would perhaps be more appropriate on an occasion like this. But unfortunately,—or shall I say, fortunately for our subject,--Mathematics is so ancient and its field of study so vast that I feel quite unequal to the task of attempting such a survey, for it would perhaps require hours to give anything like even a rough idea of its achievements or of the manifold directions in which it is rapidly growing . As such a general survey is out of the question in view of the shortness of the time at my disposal, I have decided to confine myself to some general remarks about Mathematics and Mathematical Studies in Free India. It is not my intention to give any learned discourse for consumption at high level, nor do I claim to say anything particularly original. In deviating from the beaten track, therefore, I must crave the indulgence of the learned professional mathematicians who are assembled here and who may not be a little bored by the somewhat rambling talk that I may be giving.

What then is this Mathematics,—this Queen of the Sciences as it is said to have been styled by Gauss? Is this really an apt description of the Science and, if so, how? Or, is it not more sensible to call it the "Handmaid of the Sciences" as it has also been described by many? Is there any sense in which the study of the subject is profitable either to the individual or to the society or to the State? Or, are those engaged in Mathematical Studies merely wasting their time and energy in idle and fruitless speculations which are of no use to anybody? Why is it that very few of the most capable among the young men of our country, who are endowed with the highest intellect, take to Mathematics as a profession? These are some of the questions which I shall try to answer in this discourse. Such questions are not new. They have been asked in other countries and answers have been given by professional mathematicians and philosophers interested in mathematics as well as by other great educationists. I am not however aware that the general public in this country has ever given any serious thought to such questions or demanded answers to them. It seems to me that no earnest attempt has ever been made by even the educated public in this country to understand the nature of the subject or the various aspects of mathematical studies and their relations to other fields of study, and the influence of mathematics on present-day civic life. Nor has any attention been paid to the need for improvement in the curricula and methods of teaching of mathematics, particularly of high school mathematics, as has been done from time to time in other countries. The main purpose of my address today is to focus public attention on such questions as have been mentioned above so that the various bodies and administrators responsible for the organisation and functioning of our educational system may be moved a little from their hitherto complacent attitude and do something for the re-organization and re-orientation of mathematical studies in this country. I also hope that some parts of my address may help our young friends,—the mathematicians of the future,—to have a better appreciation of the true nature of our subject and induce them to pursue their studies and research with greater zeal and energy, and that they will realise that after all they belong to one of the noblest of professions and are really not members of that curious species of human beings, cranky and idiosyncratic, as they are generally supposed to be.

To describe in precise language what Mathematics is, is an almost insuperable task. It is almost as undefinable as some of its basic concepts like point, line, angle etc., for after all these are the constituents out of which the science is constructed. Attempts have, however, been made by various thinkers to give some idea of the content of Mathematics by broadly dividing it into two categories, namely, Pure and Applied. Said Francis Bacon[1] "Mathematic is either Pure or Mixed. To Pure Mathematic belong those sciences which handle Quantitiy entirely severed from matter and from axioms of natural philosophy. Mixed Mathematic has for its subject some axioms and parts of natural philosophy, and considers quantity in so far as it assists to explain, demonstrate and actuate these". According to Sylvester[2], "the object of pure physic is the unfolding of the laws of the intelligible world; the object of pure Mathematic that of unfolding the laws of human intelligence". "Pure Mathematics", says Bertrand Russell[3], "is the class of all propositions of the form 'p implies q', where p and q are propositions containing one or more variables, the same in the two propositions, and neither p nor q contains any constants except logical constants. In addition to these, Mathematics *uses* a notion which is not a constituent of the propositions which it considers—namely, the notion of truth.'' ''Mathematics'', according to Howison[4],—and here obviously Applied Mathematics is meant,—''is that form of intelligence in which we bring the objects of the phenomenal world under the control of the conception of quantity''. These are only a few samples of the numerous descriptions and definitions that have been given by various learned men at different times. Perhaps it will not be very inaccurate to say that Pure Mathematics is the mathematics of the spirit while Applied Mathematics is the mathematics of matter, the one is a thing having its root in the mind while the other has its root in the external world, the former is built mainly on ideas and imaginations while the latter is built mainly on observations and perceptions of the universe around us through our senses, that Pure Mathematics, specially in its higher parts, is more an art than a science, while Applied Mathematics is more a science than an art, Pure Mathematics is the flower of the tree of Mathematical knowledge while Applied Mathematics is its fruit. The various definitions that have been given more or less reflect the mode of thought pursued by those who have given those definitions and have been somewhat coloured by their personal attitudes towards the content of Mathematics. And the very fact that so much thought has been given to the exposition of the contents and objectives of mathematics shows that the concepts and purposes of mathematics have not always been easy to understand. Thus while Felix Klein[5] declared that ''Mathematics in general is fundamentally the Science of *Self-evidents* (selbstverständlichen)'', we have Alfred Pringsheim[6] declaring, ''Experience however shows that for the majority of the cultured, even of scientists, mathematics remains the science of the *incomprehensibles* (unverständlichen)''.

From what I have said above about Pure Mathematics and Applied Mathematics as forming the two broad categories into which Mathematics is divided, it might be thought that they are really two distinct branches of knowledge separated from each other into water-tight compartments. As a matter of fact, however, they are not so. The two are complementary to each other and form together one great, if not the greatest, achievement of the human mind. They go hand in hand each supporting, nourishing and enriching the other, and helping each other in their onward march of progress. Pure-Mathematicians supply the tools which Applied-Mathematicians apply to problems of Nature, and just as the needs of a craftsman who sometimes finds his tools inadequate for his purposes lead to the devising and invention of new and improved tools, so also the needs of the applied-mathematicians often lead to the emergence of new notions and inventions of new branches of Pure-Mathematics. A simple instance, but none the less significant on account of its apparent simplicity, is that of the notion of *function*, ''that flower of modern mathematical thought,'' as McCormack[7] puts it. The notion of a *function* in its modern form, which is indeed the soul of modern analysis, owes its origin to investigations of applied-mathematicians. It is true that the notion of functionality, that is the relation of one variable to another, probably goes back to Descartes but it does not appear that he anywhere used the word *function* explicitly. Moreover his concept was limited to continuous functions only, such as are met with in Analytical Geometry. It is now believed that the word was first introduced in 1694 by Leibnitz[8] and was subsequently used by James Bernoulli[9] in a somewhat general sense. Euler[10] was perhaps the first to use the now familiar notation of $f(x)$. He defined a *function* of a variable quantity as "an analytical expression composed in some way of that variable quantity and of numbers or constant quantities". This definition still lacks the generality of the modern notion of a function. The necessity for an extended notion of a function was first felt by D'Alembert and Fourier in their investigations on problems of applied mathematics, namely, the vibrations of stretched strings and the conduction of heat. It was Fourier who first conceived the notion of a *single function defined in different parts of an interval by different expressions* and the credit of giving almost the present day shape to the notion of a function goes to Lejeune Dirichlet[11] who was led to his definition in connection with his investigations on the convergence of Fourier Series and thus laid the foundation of the modern theory of functions.

The above is only one of various instances which can be given to show that many brahches of pure mathematical studies have their birth in ideas derived from the pursuit of Applied Mathematics. Indeed the whole science of Geometry may be said to have originated in Applied Mathematics since it arose out of investigstions in the spatial relations of material objects. The science of Infinitesimal Calculus,—at any rate the rapid progress of it,—may be ascribed to the need for suitable mathematical tools for the study of problems of Astronomy and Mechanics. Speculations in Pure Mathematics, on the other hand, have often given rise to startlingly revolutionary theories in Applied Mathematics. Thus the General Theory of Relativity propounded by Einstein would probaly have been delayed very considerably, had not the field been prepared, as if solely for this purpose, by the development of Tensor Analysis by Riemann and Christoffel and of the Absolute Calculus by Ricci and Levi-Civita. It is therefore essentially senseless to regard Pure and Applied Mathematics as divorced from each other. "Progress has brought about", says Nunn[12], "and, indeed, has required division of labour. A Lagrange or a Clerk Maxwell is chiefly concerned to enlarge the outer dominion of mathematics over matter ; a Gauss or a Cantor seeks rather to perfect and extend the minor realm of order among mathematical ideas themselves. But these different currents of progress must not be thought of as independent streams. *One never has existed and never will exist apart from the other.* The view that they represent wholly distinct forms of intellectual activity is partial, unhistorical, and unphilosophical."

In the domain of Pure Mathematics again we talk of the different branches of it, as if they entailed altogether different lines of thought. Geometry, for instance, is sometimes supposed to be essentially different from Analysis. This however is not really so. "Sylvester remarked as curious," so says MacMahon[13], "that notwithstanding he had always considered the bent of his mind to be rather analytical than geometrical, he found in nearly every case that the solution of an analytical problem turned upon some simple geometrical notion, and that he was never satisfied until he could present the argument in geometrical language." Indeed a wonderful advance in Geometry has been brought about in recent times by the powerful tools of research of modern Analysis. All mathematics, in fact, is organically united inspite of apparent diversities in its contents. As Hilbert[14] said: "Mathematical Science ...... is an indivisible whole, an organism whose vitality is conditioned upon the connection of its parts. ...... The farther a mathematical theory is developed, the more harmoniously and uniformly does its construction proceed, and unsupected relations are disclosed between hitherto separated branches of the science."

Let us now consider for a moment some of the functions and characteristics of mathematical knowledge. As Applied Mathematics consists in the applications of Pure Mathematics I shall confine my remarks only to Pure Mathematics which I have described as the flower of the tree of mathematical knowledge.

In the first place, Mathematics is a sort of language which enables us to express our conceptions about spatial relations and quantity in a manner which can be easily understood. According to Henri Poincaré[15], "Without this language most of the intimate analogies of things would have remained forever unknown to us; and we should forever have been ignorant of the internal harmony of the world, which is the only true objective reality." Indeed Mathematics is perhaps the most perfect vehicle for the communication of human thought in as much as mathematical language is concise and at the same time precise, leaving no room for vagueness or ambguity. Hence it is the language of all the sciences,—physical, chemical, biological, social and even mental. "Through it, as it were, nature herself speaks; through it the Creator of the world has spoken, and through it the Preserver of the world continues to speak."[16] Indeed most of the physical sciences and a great deal of the essentials of the other sciences as developed today must remain unintelligible and shrouded in mystery to those who have not received adequate training in mathematical analysis. The language of mathematics is naturally condensed embodying, as it does, the result of a great deal of thinking in the form of formulas and equations and, as Pringsheim[17] puts it, "the mathematician who knows how to think in this marvellously condensed language is as different from the mechanical computer as heaven from earth."

Mathematics is, however, not merely a language to the scientist,—it is the most powerful tool in his hands which enables him to probe into the secrets of nature in his attempts to discover what he regards as the 'Laws of Nature.' This use of Mathematics as a tool is however looked down upon by many mathematicians, particularly those with a philosophical bent of mind, while others have equally severely condemned all speculative mathematics having apparently no practical value. Thus we have from Macaulay's writings[18]: "The opinion of Bacon on this subject (Geometry) was diametrically opposed to that of the ancient philosophers. He valued Geometry chiefly, if not solely, on account of those uses which to Plato appeared so base.......He condemned with severity the pretensions of the mathematicians, '*delicias et fastum mathematicorum.*'......Mathematical Science, he says, is the handmaid of natural philosophy; she ought to demean herself as such; and he declares that he cannot conceive by what ill chance it has happened that she presumes to claim precedence over her mistress." We have on the other hand the following[19] about Archimedes; "Archimedes was not free from the prevailing notion that geometry was degraded by being employed to produce anything useful. It was with difficulty that he was induced to stoop from speculation to practice. He was half ashamed of those inventions which were the wonder of hostile nations, and always spoke of them slightingly as mere amusements, as trifles in which a mathematician might be suffered to relax his mind after intense application to the higher parts of his science." Now whatever may be said for or against the use of mathematics as a tool,—and everybody is well aware of the marvellous achievements of science to the lasting benefit and welfare of humanity made possible by such use,—there is no gainsaying the fact that the use of mathematics as a tool has led to great advancements of Pure Mathematics. The Applied-Mathematician need therefore have no reason to be ashamed of his activities, indeed he may be well proud of them. He may very well remind the Pure-Mathematician that perhaps the greatest achievement of the human intellect was the discovery of the law of universal gravitation, an achievement of the applied mathematician in Newton. Thus it is idle to decry the employment of Pure Mathematics as a tool, for it is this very use which has in a great measure contributed to the progress of mathematics as pure thought.

While mathematics is no doubt a language as well as a tool, the real nature of mathematics far transcends these aspects of it, although to the uninitiated, perhaps those are the very aspects which would be more appealing than anything else. "Mathematics," said Henri Poincare[20], has a triple end. It should furnish an instrument for the study of nature. Furthermore it has a philosophic end, and, I venture to say, an end esthetic. It ought to incite the philosopher to search into the notions of number, space and time; and, above all, adepts find in mathematics delights analogous to those that painting and music give....... Hence I do not hesitate to say that mathematics deserves to be cultivated for its own sake, and that the theories not admitting of application to Physics deserve to be studied as well as others." Indeed Mathematics can be truly regarded as a fine art. It is said[21] that music had been classed as a branch of mathematics for at least two thousand years until about the year 1500. Like every other fine art, mathematics has an ennobling influence on the human soul, the value of which is inestimable. The great joy and thrill which a mathematician experiences when he hits upon a brilliant new idea is simply indescribable. He has, at any rate for the time being, an escape from the entanglements of the mundane affairs of the world and almost loses himself in a trance. I had once been talking to a friend who is a teacher of literature and he told me that he had found mathematics very dull and uninteresting and could not understand how any one could be interested in it. I thought I would give him a very simple and easily understandable illustration and asked him to verify and contemplate the following equations:

$$1^3 = 1^2$$
$$1^3+2^3 = (1+2)^2$$
$$1^3+2^3+3^3 = (1+2+3)^2$$

He agreed that the equations were correct and appeared to be interesting. I asked him whether he would not infer anything from the above and he immediately said that he was wondering whether it was not also true that

$$1^3+2^3+3^3+4^3 = (1+2+3+4)^2$$

When I assured him that it was true and that the inference could be easily extended to any number of consecutive positive integers starting from 1, he was surprised and thrilled to find that the natural numbers which seemed to be devoid of any beauty had such a beautiful property, full of symmetry and harmony. This of course is a trivial illustration to show that even a non-mathematician can appreciate the beauties of mathematics and be thrilled and delighted by such experience. The joy of the person who hits upon a new idea and invents a new theorem of mathematics is like that of an artist who creates something out of his imagination or of a musician who composes a beautiful symphony in which his very soul, as it were, tries to find expression. Thus when Bolyai, while still a student at Vienna, had conceived the idea of an Absolute Geometry which would contain Euclidean Geometry as a special case and had worked out the main ideas of non-Euclidean Geometry based on a new theory of parallels, he wrote to his father expressing his desire to publish the results of his investigations on the theory of parallels, "for", he wrote[22], "I have made such wonderful discoveries that I am myself lost in astonishment, and it would be an irreparable loss if they remained unknown. When you read them, dear Father, you too will acknowledge it. I cannot say more now except that out of nothing I have created a new and another world. All that I have sent you hitherto is as a house of cards compared to a tower." He found the investigation of the famous parallel postulate so interesting and exciting that he pursued it "inspite of his father's solemn adjuration to let the loathsome subject alone." Similar joy and excitement must be experienced by every mathematician who conceives a new idea and creates something new in the realm of mathematical knowledge. Mathematics, like poetry, is a a creative art and not merely a collection of formulas or statements of what are called "mathematical truths." Hence it is that imagination plays such an important role in the progress of mathematics. Says Thomas Hill[23]: "Mathematics and Poetry are ... the utterance of the same power of imagination, only that in the one case it is addressed to the head, and in the other, to the heart." And again[23], "Mathesis and Poetry are of the closest kindred, for they are both works of the imagination. Poesy is a creation, a making, a fiction; and the Mathematics have been called, by an admirer of them, the sublimest and most stupendous of fictions." According to Voltaire[24], "there was far more imagination in the head of Archimedes than in that of Homer." Indeed Mathematics has a great deal in common wtih the fine arts. From it the human mind derives through the intellect essentially the same kind of pleasure as it does from a piece of painting through the eye, or from a piece of music through the ear. It is moreover the most innocent of such pleasures, being a spiritual pleasure having nothing to do with the senses, while the pleasures derived from painting or music may be said to have something of the sensual about them.

A little while ago I gave a very simple illustration of beauty in mathematics. Indeed many of the theorems of mathematics are extremely beautiful, their beauty consisting in their simplicity and often in the harmony of their contents. "A peculiar beauty reigns in the realm of mathematics." says Kummer[25]," a beauty which resembles not so much the beauty of art as the beauty of nature." Says Bertrand Russell:[26] "Mathematics, rightly viewed, possesses not only truth but supreme beauty—a beauty cold and austere, like that of sculpture, without appeal to any part of our weaker nature, without the gorgeous trappings of painting or music, yet sublimely pure, and capable of a stern perfection such as only the greatest art can show." No one can fail to be deeply impressed and fascinated by the beautiful contents of many of the theorems of Geometry, as such theorems can be visualised to a great extent and the beauties of them thus perceived easily. The beauty of the famous Pythagorean theorem of the right-angled triangle is an almost unsurpassable one, so much so that it formed the subject for the composition of a poem. But beauty in mathematics is not confined to Geometry alone. Here is another illustration from the domain of numbers:

Consider the following two sequences of positive integers:

(A) 1, 3, 6, 10, 15, 21, 28, 36, 45, 55, 66, 78, ...

(B) 1, 4, 9, 16, 25, 36, 49, 64, 81, 100, 121, 144, ...

The first sequence (A) is the sequence of what are known as the triangular numbers while the second (B) is the sequence of squares. Looking at the two sequences as far as written above one sees that 1 and 36 are the only two numbers occurring in both (A) and (B) and one can easily verify that there are no other numbers among the first 48 numbers of (A) which also belong to (B), the next number having this property is the 49th number which is $1225=35^2$. It is only natural to feel a little curious and ask the question "Are there other common members of (A) and (B), i.e. are there other numbers besides 1, 36 and 1225 which are triangular as well as square? Are there a finite or an infinite number of such numbers and how can they be determined?" Now the answer to these questions is completely contained in the symbol $\sqrt{2}$. One might at first feel surprised and ask, "what has the irrational number $\sqrt{2}$ got to do with the question which concerns two special subsets of the natural numbers?" All the same it is true that $\sqrt{2}$ contains the complete answer to the question and this is how it does: Let $\sqrt{2}$ be expressed as a simple continued fraction and let its successive convergents be written out in a sequence. This sequence is:

$$\text{(C)} \quad \frac{1}{1},\ \frac{3}{2},\ \frac{7}{5},\ \frac{17}{12},\ \frac{41}{29}\ \ldots\ldots\ldots\ldots\ldots\ldots$$

The sequence can be easily written down to any number of terms by the simple rule that the numerator of any term beginning from the third is obtained by multiplying the numerator of the preceding term by 2 and adding the result to the numerator of the next preceding one. The same rule applies to the demominators also. Thus for the 5th term $\frac{41}{29}$, we have

$$41 = 2\times 17+7$$
$$29 = 2\times 12+5$$

Now it can be proved without much difficulty, though not quite trivially, that the only numbers which are both triangular as well as square are those of the infinite sequence

$$\text{(D)} \quad (1.1)^2,\ (3.2)^2,\ (7.5)^2,\ (17.12)^2,\ (41.29)^2,\ \ldots\ldots\ldots\ldots\ldots\ldots$$

These are respectively the 1st, 8th, 49th, 288th, 1681st, ... triangular numbers as well as the 1st, 6th, 35th, 204th, 1189th, ... square numbers. A glance at (C) shows how the terms of (D) are derivable from the corresponding terms of (C).

I have, in the preceding lines, often spoken of 'mathematical truths' and 'natural laws'. There is however a good deal of misunderstanding about the sense in which the words 'truth' and 'law' are generally used and a few words about them may not be altogether out of place. The word 'law' in common parlance means something which has necessarily to be obeyed by the objects to which they apply. Similarly the word 'truth' usually implies an attribute which is of an objective nature and a true proposition is supposed to be one which cannot be controverted by anybody under any circumstances. These words, however, have slighly different meanings in mathematics. A 'law of nature' in reality means a description in mathematical language the results of various observations regarding the behaviour of certain physical entities under similar circumstances. Some hypothesis regarding the properties of those entities is made to explain their behaviour and the hypothesis is tested by further observations and experiments, and if the results of the experiments, carried out with the help of such apparatus as are at the command of the scientists at that time, agree with the theoretical results obtained by calculations on the basis of the hypothesis, then the hypothesis is called a 'law'. Thus the laws of applied mathematics, are not really entirely of an objective nature as they depend on so many other factors. Hence they have to change with the progress of science and refinement of the methods of measurement of observed quantities. Sometimes the laws are only slightly modified and sometimes they have to be totally discarded, perhaps to be re-accepted, at least partially, in a new garb. It is therefore not quite correct to think of what is called a law of nature as something like a permanent, ultimate and incontrovertible truth. "In most sciences," says Hermann Hankel[27] "one generation tears down what another has built and what one has established another undoes." Indeed the formulation of new laws are sometimes based on ideas which completely revolutionise the current notions of the physical world. Thus Newton's laws of mechanics and his law of gravitation brought about a revolution in the sense that these gave us probably for the first time an absolute space and an absolute time, independent of each other, and the doctrine of invariability of mass. Another and perhaps even greater revolution was brought about when nearly two centuries after the death of Newton, Einstein propounded his General Theory of Relativity which dashed to the ground all the above three concepts about space, time and matter. On the other hand it is well known how Newton's theory of light as being composed of fast moving particles was discarded in favour of a Wave Theory according to which light consisted merely in the vibrations of an all-pervading medium, the ether, and how again in the recent past the theory of light-quanta all but resuscitated the corpuscular theory from its grave. "The certainties of Science," says Whitehead[28], "are a delusion. They are hedged around with unexplored limitations." The laws of nature have therefore to be constantly sent back to the crucible and recast in the light of new experiences, observations and improved measurements. Thus writes Bertrand Russell[29] about laws of nature: ' 'The theory of relativity has shown that most of traditional dynamics, which was supposed to contain scientific laws, really consisted of conventions as to measurement, and was strictly analogous to the "great law" that there are always three feet to a yard. In particular, this applies to the conservation of energy. This makes it plausible to suppose, that every apparent law of nature which strikes us as reasonable is not really a law of nature, but a concealed convention, plastered on to nature by our love of what we, in our arrogance, choose to consider rational." A mathematical truth, or what is sometimes called a law of mathematics, stands, however, on a somewhat different footing. Even so, there are some apparently conflicting views which, it seems to me, arise not so much from the intrinsic nature of the matter as from the angle of vision from which we look at it. Bertrand Russell[30], for instance, holds the view that "Pure Mathematics consists entirely of such asservations as that, if such and such a proposition is true of *anything*, then such and such another proposition is true of that thing. It is essential not to discuss whether the first proposition is really true, and not to mention what the *anything* is of which it is supposed to be true. . . . . Thus mathematics may be defined as the subject in which we never know what we are talking about, nor whether what we are saying is true." Nobody would however deny the intrinsic truth of the Fundamental Theorem of Arithmetic, namely, that every natural number, i.e. a rational positive integer, except 1 is, apart from the order, uniquely representable as a product of the natural primes, or of the statement that $2+2=4$. Such statements are of the nature of absolute and eternal truths about the objects or concepts to which they apply. Pure Mathematics, however, does not consist essentially of absolute or eternal truths in the above sense, for much of the truths of modern mathematics can be styled as such only in a relative sense, although in a somewhat limited sense they may also be described as absolute truths. As a matter of fact in most cases, it is perhaps non-sensical to ask whether a certain mathematical result is either true or false. For instance, it is non-sensical to ask whether the statement $(a+b)^2 = a^2+2ab+b^2$ is true or false unless it is specified what a and b stand for. Mathematicians, however, for a long time believed in the absolute truth of mathematical theorems in the sense of their infallible applicability to human experiences of the physical world although occasionally there have been some sceptics who have questioned such dogmatic beliefs. But this view about the absolute character of mathematical truths was perhaps finally abandoned only after the invention of non-euclidean Geometry by Bolyai and Lobachewsky who showed that there could be consistent geometries other than the Euclidean which might be just as true or as false in their applications, but so far as they were constructions of mathematical systems based on well defined elements and postulates, each was as true as any other; in fact each might be regarded as absolutely true in its own world of ideas. "Modern Mathematics", we may agree with Huxley[31], "is that which knows nothing of observation, nothing of experiment, nothing of induction, nothing of causation," in so far as modern pure mathematics is born of imagination and inspiration of the mind rather than of experiences of nature, although it may be true that the inspiration often comes from such experiences; as for instance, Euclidean Geometry derives its inspiration from spatial experiences. Fired with an inspiration, the pure-mathematician weaves his ideas into a pattern utterly regardless of any consideration of application or profit. Whether the pattern woven by him has any counterpart in Nature is a matter of supreme indifference to him. Whether the natural phenomena to which his system is sought to be applied agrees with the pattern evolved by him or not is of no significance since the pattern was created for its own sake and not with the purpose of interpreting any natural phenomenon by a reference to it. Disagreements therefore do not falsify his system in any sense,—the system in its own framework remains eternally true.

Another aspect of mathematical activity consists in its being perhaps the most harmless of human activities. It is not actuated by any ulterior motives, nor contaminated by any earthly desires, for it does not concern the material world at all. As Hardy[32] says: "Both Gauss and lesser mathematicians may be justified in rejoicing that there is at least one science, and that their own, whose very remoteness from ordinary human activities should keep it gentle and clean."

Thus Mathematics being an embodiment of "সত্যম্ শিবম্ সুন্দরম্" the true, the good and the beautiful,—the three principal attributes of Godhood in Hindu Philosophy,—is perhaps the one Science, the disinterested and devoted pursuit of which, more than that of any other, takes man nearer to his Creator.

Now it may very well be asked, if mathematics has really the attributes described above, why is it then that it has so few votaries in this country,—this land with its rich and splendid heritage of spiritualism from time immemorial? My answer is that there are many factors responsible for this, but perhaps the most potent factor is the present general attitude of the people towards the need for the acquisition of mathematical knowledge and its place in a general scheme of education. Most people seem to think that the teaching of higher mathematics is wasteful and that it is enough for all ordinary purposes to learn the elementary rules of Arithmetic. There is accordingly a demand in some quarters for reducing the curriculum in mathematics for the Matriculation Examination to elementary Arithmetic only. Let us therefore consider a little the place and scope of mathematics in the High School curriculum. It seems to me that sufficient serious thought has never been given to this question. Perhaps this may be accounted for by the fact that due to two centuries of slavery and an educational system imposed on us by considerations other than the genuine welfare and progress of the people we were not free either to chalk out our own programme of education or, even if we could do so, to enforce it. Now, however, conditions have changed, our country is free and Free India demands an immediate and searching examination of our educational problems and a re-casting of our educational system in a form that will enable us to occupy an honourable and important place in the comity of nations at the earliest possible date. Our people, unfortunately, are not well informed in educational matters and we must admit, with shame, that we, who belong to the teaching profession, have done next to nothing to see that they are better informed about our subject. We have no organisation like the National Council of Teachers of Mathematics of the United States of America or the Mathematical Association of the United Kingdom, nor any journal of the standard of the Mathematics Teacher or the Mathematical Gazette through which we could come into contact with school teachers and the general public and acquaint them with our aims and ideals. And no plan of reform in any field can be effective unless it has sufficient support of the general public.

Now, what is the real purpose for which mathematics is or should be taught? Is it justifiable to include it as a compulsory subject in the high school curricula for all students when it is well known that a large percentage of the matriculates will never require the use of it in the discharge of their vocations? The following extract[33] from the Report of the National Committee on Mathematical Requirements of the Mathematical Association of America perhaps gives an adequate answer:

> "The primary purposes of the teaching of mathematics should be to develop those powers of understanding and of analyzing relations of quantity and of space which are necessary to an insight into and control over our environment and to an appreciation of the progress of civilisation in its various aspects, and to develop those habits of thought and of action which will make these powers effective in the life of the individual."

There is of course also what may be called a secondary purpose, though not applicable to all, namely that of equipping the students for training in the technical sciences which is so necessary for the material welfare of humanity at large and also, in a somewhat narrower sense, for the management of statecraft and defence of the nation. But it is essentially for the primary purposes mentioned above that mathematics of a fairly high standard has an important and almost mandatory place in any scheme of general education in every progressive country of the world. Unfortunately this has not been properly understood or appreciated by the educated public in this country who still think of Mathematics as a computer's art and do not realise that[34], "Mathematics is no more the art of reckoning and computation than architecture is the art of making bricks or hewing wood, no more than painting is the art of mixing colours on a palette, no more than the science of geology is the art of breaking rocks, or the science of anatomy the art of butchering." This aspect of the aim of teaching mathematics will perhaps not be properly recognised by any but a very limited circle of our people until school Mathematics is sufficiently reformed and the curriculum and standard of teaching are made of a slightly more advanced character in order to provide some inkling of the vital role which mathematics plays in modern life and the profound influence it has brought to bear on all departments of thought. "In the Secondary Schools," says H.G. Wells[35], "Mathematics should be a part of general culture and not contributory to technical training of any kind. . . . . Mathematics is a quite indispensable factor of general education in so far as the latter shows its traces in the comprehension of the development of civilisation and the ability to participate in the further tasks of civilisation." It is therefore necessary to reform school education suitably so as to introduce the notion of functionality even at the school stage for, as Klein said, "the world is being functionally minded" and without a notion of functionality it is not possible for anyone to understand modern civilisation and its trends. It will be pointed out, I know, that the curriculum of school mathematics is heavy enough and nothing more can be added to it. But that is exactly my point,—it is loaded with a good deal of rubbish which can be safely scrapped. This should be done and a reformed and revitalized curriculum should be framed as early as possible. The movement for reforms in the curricula and methods of teaching of mathematics first started in Germany more than a century ago in 1816, when the programme known as the Prussian Lehrplan was formulated. What wonder then that Germany became the home of mathematical learning and the Germans more scientifically advanced than all other nations? This Lehrplan however did not prove quite satisfactory and had to be modified from time to time. The reform movement continued and in 1873, when the country had begun to settle down after the Great War of 1871, the Prussian Minister of Education summoned a conference to discuss the question of mathematicl education in all its bearings. At about this time the movement spread into France and early in the twentieth century it spread to other European countries and America as well. I need not go into the detailed history of the progress of this movement but it is worthwhile to mention that as a result of the discussions held at the Fourth International Congress of Mathematicians at Rome in 1908, a committee known as the "Internationale Mathematische Unterrichts Kommission" (International Commission on the Teaching of Mathematics) was set up with Felix Klein as its Chairman, for the purpose of studying and comparing the tendencies in the teaching of mathematics in various countries and submitting a report to the next meeting of the Congress. A National Committee on Mathematical Requirements was set up in America and their report entitled "The Reorganisation of Mathematics in Secondary Schools" published in 1923 'is generally recognised as a landmark in the history of American mathematical education.' Most nations have had their own national committees and have profited by the study of the reforms proposed and carried out in other countries. In India alone the century-old out-worn programme with hardly any reform is still being followed. Any attempt at reform made by professional mathematicians here and there have been, as I know from personal experience, stubbornly opposed by our educational senators most of whom have no idea of what mathematics is. The following criticism of the guardians of American secondary education made by Dr.

Jesse Newlon at the 1932 Conference on Secondary Education seems to me to be very well applicable to conditions in India even in 1950:

> The American secondary school is a stronghold of conservation where the curriculum is hopelessly traditional and not vitally connected with the needs of youth. The inertia of the secondary school is tremendous. Its teachers and administrators, with few exceptions, are but stereotypes of an outworn concept of education. Every attempt to effect fundamental changes have been stubbornly resisted by a majority of its personnel.

This state of affairs is principally due to the fact that even the educated section of the public, not to speak of the general public, hardly realise that "every major concern among the intellectual concerns of man is", as Professor Keyser[36] puts it, , "a concern of mathematics" and that tne study of some advanced mathematics is important not simply because of its utilitarian value in the narrow sense as a master tool for sicentific inventions, but chiefly because in our modern civilisation it has to be regarded as one of the Humanities, the study of which is indispensable for a rational life ; for it inculcates the habit of correct thinking and "correct thinking based on true premises secures the mastery of the world"[37]. The world we live in is not static. Change is the great Master that inexorably and pitilessly rules us all and we should not forget that "mathematics consists mainly in the study of functions and the study of functions is the study of the ways in which changes in one or more things produce changes in others"[38].

If all that has been said above be granted, then it is incumbent upon us to formulate a plan of teaching mathematics which will be interesting enough to attract even students of average ability. The present position in schools is however such that the very name of mathematics is a bugbear to even some of the best intellects who shrink from it with a sense of horror and disgust and keep away from it as soon as they have passed the school stage when it is no more a compulsory subject of college studies. Now what should we do to remedy this state of affairs ? I shall mention only some of the things which I think should be done without any delay.

First, a reform of the school curriculum is absolutely necessary. All non-essentials,—and there are quite a lot of them,—should be ruthlessly weeded out and such new matters should be included as would give the young learners a glimpse of the true and beautiful in mathematics and awaken in them a curiosity to learn more of the subject and to dive deep into its pools of everlasting joy and pleasure.

Secondly, the method of teaching mathematics should be revised so as to introduce the aspect of rigour, even at the school stage, wherever possible. I know there are many who will object to the introduction of rigour at this stage but let us see what some great savant have to say about it. Pringsheim[39] says, "I have come to the conclusion that the exertion, without which a knowledge of mathematics cannot be acquired, is not materially increased by logical rigour in the method of instruction". According to D'Alembert[40] "the only way in which to treat the elements of an exact and rigorous science is to apply to them all the rigour and exactness possible. And Hilbert[41], one of the greatest mathematicians of the recent past, declares : "It is an error to believe that rigour in proof is an enemy of simplicity. On the contrary we find it confirmed by numerous examples that the rigorous method is at the same time the simpler and the more easily comprehended". The baneful effect of neglecting rigour where it can be easily applied can hardly be over-emphasised. Loose thinking in the initial stages engenders a habit of mind from which it is difficult to extricate oneself at a later stage when rigorous thinking is indispensable. To quote Whitehead[42]: "When the initial statements are vague and slipshod, at every subsequent stage of thought, common sense has to step in to limit applications and to explain meanings. Now in creative thought common sense is a bad master. It can only act by suppressing originality."

Thirdly, teachers of mathematics should be selected with the utmost care. It should be borne in mind that no teacher can be really effective as a teacher if the range of his knowledge extends only as far as or just beyond the course he has to teach. Not infrequently it happens that a university or college student has to unlearn certain things which he has previously 'learnt', and it is always more difficult to unlearn than to learn. It is not enough that a teacher has been trained in the *methods* of teaching at a teachers' training college which is usually regarded as a sufficient guarantee of his teaching ability . It is good to know the method but what does it avail if he has not acquired mastery over the content? And it is impossible for any one to acquire such mastery unless his knowledge extends well beyond the subject matter of his teaching.

Fourthly, text books, before they are placed in the hands of young learners, should be critically examined as to the statements and proofs given therein even if they are judged to be suitable otherwise. Sometimes for want of a really good text -book it may be necessary to prescribe a badly written book but in all such cases it should be possible for the teacher to point out the defects and to supplement the book by his own teaching.

In what I have stated above I have only tried to emphasise the need for reform and not to give any but a very rough outline of the lines along which reform should be carried out. I have only tried to show that while other nations were awakened by pressing needs long ago, we have all this time been deep in slumber. They have forged ahead and we are lagging miles behind. It is therefore high time that we also exert ourselves in effecting much needed reforms and try to set our house in order. But no effort in this direction can be fruitful unless it is made in an organised manner and is backed by public opinion. It is perhaps pertinent to ask what our national governments, central and provincial, have done in this matter. Perhaps it will be said that the Central Government has not been unmindful of its responsibility and had recently appointed a strong Universities Commission, the report of which has been submitted though not yet published.* While heartily appreciating the laudable desire of the Government for necessary reforms in University education, may I suggest without any disrespect to Government that a Commission of the type appointed by Government can only make recommendations,—perhaps very wise recommendations,—regarding the organisation of education, but they can hardly make any recommendations regarding curricula in general. It seems to me therefore that the report of the Commission will contain hardly anything helpful for the solution of the problems I have been discussing. I suggest that a special committee be set up without delay, with appropriate sub-committees, to go into the question of mathematical studies in our schools, colleges and universities, in view of the fundamental role which mathematics plays in human affairs generally and the sciences in particular. The scientific age is far too advanced to brook any delay in this matter and the sooner it is realised, the better for the country and the nation.

So far I have referred to only one of the factors responsible for the present unsatisfactory state of progress of Mathematics in this country, namely, the lamentable ignorance of the general public about the place of mathematics in modern education and the consequent neglect of school mathematics. There are however various other factors also contributing to this state of affairs. One of these is the fact that the main object for which a university career is sought by the youth in this country, as perhaps elsewhere also, is that of qualifying themselves for fairly lucrative jobs which would enable them to lead a more or less comfortable life. Our best brains are therefore, unfortuntely for our country, attracted to those subjects, which are likely to bring good dividends to the largest number, and mathematics is not one of these dividend-earning subjects. Another reason can perhaps be found in the nature of the question papers in mathematics set for the various competitive examinations conducted by our public service commissions which many of our gifted young men make up their minds to take, even from the beginining of their university career. So far as I know the questions in mathematics usually asked at most of these examinations demand a very highly developed skill in manipulation and the ability to solve most complex and complicated problems like those asked in the old Cambridge Tripos Examinations. It is difficult to understand the object of such a test in mathematics for the recruitment of administrative officers. One should have thought that mainly such questions would be asked as are likely to bring out the real mental faculties of the candidates,—their power of comprehension, logical thinking and lucid exposition,—rather than the ability to solve antiquated problems which is hardly of value in any walk of life. Since mathematics is not a compulsory subject, the candidate who has to offer mathematics as one of the subjects of examination is severely handicapped in comparison with one who can avoid it. This therefore acts as a strong deterrent on even those young men who have a natural inclination for mathematics and diverts them to other courses of study after they pass the school stage to the great detriment of the progress of mathematics in our country. Lastly it seems to me mathematical studies have not so far received sufficient encouragement from Government. Our national Government has planned eleven national laboratories and technological institutions but one sadly misses in the list an Institute for Mathematical Research. Why this omission ? Perhaps because mathematics is considered a comparatively unimportant subject whose progress can wait and perhaps it is thought that researches in pure mathematics are little useful as most of them are mere speculations in thought and unrelated to the physical world. Said Voltaire[43] : "In Geometry, as in most sciences, it is very rare that an isolated proposition is of immediate utility. But the theories most powerful in practice are formed of propositions which curiosity alone brought to light and which long remained useless without its being able to divine in what way they should one day cease to be so. In this sense it may be said, that in real science, no theory, no research, is in effect useless." Lessons of history are easily forgotten and it may therefore be worthwhile to remind our countrymen that the study of Conic Sections, originated by Plato, continued to be pursued enthusiastically century after century without any apparent purpose, save perhaps for the enjoyment of the intellectual pleasure that could be derived from a contemplation of those beautiful curves and their remarkable properties. But nearly eighteen centuries afterwards, the genius of Newton was able to produce the fruit of those studies,—perhaps the most wonderful fruit of pure mathematical studies,-in the shape of his famous law of gravitiation the light of which all of a sudden illumined the universe and held out the most efficient instrument for the unravelling of its mysteries. Abstruse mathematical researches should not therefore be neglected or disdained simply because they have no application at the moment. History has shown that there is hardly any branch of abstruse mathematics which has not sooner or later found applications in unexpected and unsuspected manners. The establishment of an Institute of Mathematical Research with necessary equipments and staff can therefore be more than amply justified as a sound investment, and surely our national Government would be well advised to take early steps in the matter.

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* The report was published when this address was in the press.

I have talked long enough without however being able to touch more than a fringe of the problems that face us. I have said practically nothing about higher mathematical studies and research although I wish I had sufficient time at my disposal to be able to do so. My remarks have been mainly directed to the need for placing mathematical education in the secondary schools on a sound basis, for unless we are able to secure a strong foundation and to create a proper attitude towards mathematics, it is idle to expect any improvement in the standard of higher mathematical studies and research; and Free India must, with steadfast zeal and unswerving determination, encourage and promote such research if she is not to slide back into slavery once again. I must, however, now bring this talk to a close and I think I can do it no better than by quoting the following passage[44] which sets forth in beautiful language an appreciation of the nature of mathematics and which I am sure will strike a concordant note in every mathematician's heart:

> Coterminous with space and coeval with time is the Kingdom of Mathematics; within this range her dominion is supreme; otherwise than according to her order nothing can exist; in contradiction to her laws nothing takes place. On her mysterious scroll is to be found written for those who can read it that which has been, that which is, and that which is to come. Everything material which is the subject of knowledge has number, order, or position; and these are her first outlines for a sketch of the Universe. If our feeble hands cannot follow out the details, still her part has been drawn with an unerring pen, and her work cannot be gainsaid. So wide is the range of mathematical sciences, so indefinitely may it extend beyond our actual powers of manipulation that at some moments we are inclined to fall down with even more than reverence before her majestic presence. But so strictly limited are her promises and powers, about so much that we might wish to know does she offer no information whatever, that at other moments we are fain to call her results but a vain thing, and to reject them as a stone where we had asked for bread. If one aspect of the subject encourages our hopes, so does the other tend to chasten our desires, and he is perhaps the wisest, and in the long run the happiest, among his fellows, who has learned not only this science, but also the larger lesson which it directly teaches, namely, to temper our aspirations to that which is possible, to moderate our desires to that which is attainable, to restrict our hopes to that of which accomplishment, if not immediately practicable, is at least distinctly within the range of conception.

REFERENCES

1. Bacon, Francis. *Advancement of Learning*, Bk. 2.
2. Sylvester, J J. *Collected Mathematical Papers*, Vol. 3, p. 424.
3. Russell, Bertrand. *Principles of Mathematics*, p. 1.
4. Howison, G. H. *The Departments of Mathematics and their Mutual Relations. Journal of Speculative Philosophy*, Vol. 5.
5. Klein, Felix. *Anwendung der Differential-und Integralrechnung auf Geometrie*, (1902). p. 26
6. Pringsheim, Alfred. *Jahresberichte der Deutschen Mathematikar Vereinigung* (1904), p. 357.
7. McCormack, T. J. *On the Nature of Scientific Law and Scientific Explanation*, Monist, Vol. 10, p. 555.
8. *Leibnizens. Mathematische Schriften*, Book V, p. 307
9. Bernoulli, J. *Opera*, Tome II, pp. 241, 255 and Tome III, p. 174

10. Euler, L. *Introductio in analysin infinitorum,* vol. I, p. 4
11. Dirichlet, G. Lejeune. *Ueber die Darstellung ganz willkürlichen Funktionen durch Sinus-und Cosinusreihen. Werke, Vol*— I, p. 135.
12. Nunn, T. P. *The Teaching of Algebra*,p. 16
13. MacMahon, P. A. *Proceedings of the Royal Society of London* Vol. 63, p.17
14. Hilbert, D. *Mathematical Problems. Bulletin of the American Mathematical Society*, Vol. 8, p. 478.
15. Poincaré, H. *The value of Science, Popular Science Monthly*, 1906, pp. 195-196.
16. Dillmann, C. *Die Mathematic die Fackelträgerin einer neunen Zeit*, p. 5.
17. Pringsheim. A. *Jahresberichte der Deutschen Mathematiker Vereinigung*, Bd. 13, p. 367
18. Macaulay. *Critical and Miscellaneous Essays*, Vol. I, (1879) p. 380
19. *Ibid*, p. 380
20. Poincaré, Henri. *Bulletin of the AmericanMathematical Society*, Vol. 4(1899), p.248
21. *See* p. 160 of the *Eleventh Yearbook of the National Council of Teachers of Mathematics* Columbia University, 1936.
22. *See* Sommerville's *Non-Euclidean Geometry* (1914), pp. 22-23
23. Hill, Thomas. *North American Review*, Vol. 85, pp. 229-230
24. Voltaire, *A Philosophical Dictionary* (1881), Vol. 3, p.40
25. Kummer, E. E. *Berliner Monatsberichte* (1867), p. 395.
26. Russell, Bertrand. *The Study of Mathematics : Philosophical Essays* (1910), p. 73.
27. Hankel, Hermann, *Die Entwickelung der Mathematik in den letzten Jahrhunderten* (1884), p.25.
28. Whitehead, A. N. *Adventures of Ideas*, 1933.
29. Russell, Bertrand. *The ABC of Atoms* (1925), p. 170
30. Russell, Bertrand. *Recent Work on the Principles of Mathematics, International Monthly*, Vol. 4(1901), p. 84
31. Huxley, T. H. *The Scientific Aspects of Positivism, Fortnightly Review* (1898)
32. Hardy, G. H. *A Mathematician's Apology*, (1940), p. 61
33. National Committee on Mathematical Requirements. *The Reorganizantion of Mathematics in Secondary Education*, (1923), p.11.
34. Keyser, C. J. *Lectures on Science, Philosophy and Art* (1908), p. 29.
35. *Unterrichtsblätter fur Mathematik and Naturwissenschaft* (1904), p. 128.
36. Keyser, C. J. *Mole Philosophy and other Eassays*, 1927.
37. Klein, Felix. *Jahresberichte der Deutschen Mathematikar Vereinigung*, Vol. 11, p. 13.
38. Keyser, C. J. *Mole Philosophy and other Essays*, (1927), p. 93, et seq.
39. Pringsheim, Alfred. *Jahresberichte der Deutschen Mathematiker Vereinigung*, (1898), p. 143.
40. *See* De Morgan. *Trigonometry and Double Algebra* (1849), title page.
41. *See Bulletin of the American Mathematical Society*, Vol, 8, p. 441
42. Whitehead, A. N. *Introduction to Mathematics* (1911), p. 157
43. Voltaire. *A philosophical Dictionary* (1881), Vol. I. p. 374.
44. Spottiswoode, W. *See* Sonnenschein's *Encyclopedia of Education, p.* 208.

The author is greatly indebted, for many of the quotations, to the 'Memorablia Mathematica' by R. E. Moritz, (1914).

SECTION OF STATISTICS

President : P. V. Sukhatme, Ph.D., D.Sc., F.N.I.

Presidential Address

SAMPLE SURVEYS IN AGRICULTURE

1. Introduction

1.11. I am thankful for being asked to preside over the Section of Statistics of the 37th Session of the Indian Science Congress. Having been in the Indian Council of Agricultural Research for over 10 years, it is natural that I should choose for my address a topic, in the development of which the Council has played a leading role and which has assumed growing importance in recent years. The method of sampling as a means of collecting annual agricultural statistics was almost unknown a decade ago in most provinces in India. Thanks, however, to the pioneering work of Hubback, Mahalanobis, Panse and Kalamkar, rapid and extensive developments in the method have taken place in recent years which have totally changed the situation. The particular development with which the Council is associated is the application of the sampling method to the estimation of crop yields in India. In less than a few years since the Council first initiated a sample survey on crop yields, the method was extended over the major part of India and is now being adopted as a normal routine for the estimation of yields of all principal crops in the country. In several other directions also the Council has helped to develop the uses of sampling for improving agricultural statistics. It will be my object in this address to present to you the principal developments in the field of sampling evolved as a result of this work.

2. Administrative Background

2.11. Sampling practices are influenced by the administrative background and the local conditions as much by the sampling theory itself. The former are often so important that sampling practices select themselves. It is thus necessary to know the administrative background in India for a proper appreciation of the sampling practices developed in recent years for the estimation of crop yields and other agricultural statistics.

2.12. For administrative purposes, the country is divided into 9 provinces, 9 major States and Unions of States and a few minor States and Centrally administered areas. Each province (or State) is further divided into a number of districts, each with a geographical area of about 3 to 4 thousand sq. miles. A district is divided into about 5 tehsils on the average and each of the latter is further divided into 3 to 5 circles for convenience of land revenue administration. A circle contains about 100 villages, each about 1 to 3 sq. miles in area. In Bombay and Madras, the equivalent of a tehsil is a taluka, usually much smaller than a tehsil.

2.13. The village in India is a well defined area with the dwellings clustering together and surrounded by the agricultural land. This land is divided into a number of fields which have been surveyed and mapped and given numbers called survey (khasra) numbers. The average size of a survey number in a province varies from about 0.5 to 6 acres and the average number of survey numbers in a village varies from roughly 300 to 1500 in the different provinces. The conditions in villages are thus totally unlike in U.K. and U.S.A. where a farm is several hundred acres in size and has on it the farmer's home. Again the majority of farmers in India cannot read or write. The communications between villages are also poor.

2.14 For every village or a group of few villages, usually between 2 to 6, there is a village accountant, called Patwari, one of whose major duties is to make a field to field inspection of the area under his jurisdiction and maintain a register showing the survey numbers and the names of the crops grown thereon along with the area under each. There is also a Revenue Inspector in each circle, one of whose duties is to check the registers maintained by the Patwaris in his jurisdiction. It is this feature of field to field enumeration and adequate supervision provided by the Land Records Administration which imparts to the crop acreage figures a high degree of accuracy. This system of recording acreage is naturally not available in the permanently settled areas where no such elaborate agency exists. Of the three provinces under this settlement, however, Bihar and Orissa have taken a commendable step of appointing the requisite agency and the unions of states have also begun taking the necessary steps in this direction.

3. ESTIMATION OF CROP YIELDS

3.1. *The official method*

3.11. The official method of estimating the yield per acre in any year consists in multiplying what is called the normal yield by the condition factor of the crop in that year. The determination of both these factors is, however, largely a matter of guess work under this method. For, the normal yield, which is defined as the yield on average soil in a year of average character, is fixed on the basis of the results of crop cutting experiments carried out in fields which are judged by the experimenters to bear an average crop. No objective procedure is laid down for the choice of the fields and the plots harvested within them. The condition factor is likewise subject to unknown errors, since it is a subjective estimate of the crop in terms of the normal. Usually it is expressed in terms of annas with a fixed number of annas representing the normal. The lower officials make a guess of the condition of the crop in their jurisdiction and pass on the estimates to their immediate superiors. The latter make their own guess at the figures thus reported. The final figure is fixed by the Director of Agriculture or Land Records or by both together with these figures before them. Quite naturally the yield estimates under this procedure are unreliable and have an unknown margin of error.

3.2. *Random Sampling Method*

3.21. That the official method is defective and that the only way of satisfactorily estimating the yield per acre is by conducting crop cutting experiments in randomly selected plots, has been known in India for a long time. To Hubback goes the credit of first employing this principle in practice, in his yield surveys on paddy in 1923-25 (2). Using a triangular wooden frame for marking sample plots with an area of 13.6 sq. ft. in place of 1/10 acre plots used in departmental crop cutting experiments, Hubback carried out a series of experiments on paddy evenly distributed in space and harvesting time and showed that by selecting about 12 centres in a subdivision (tehsil) and harvesting 30 to 40 sample plots on one specified day at each centre the average yield per acre could be estimated with an error of one maund per acre. There was no randomisation, however, in the modern sense of the word in Hubback's method. Sampling at any given centre was limited to those fields where harvesting was in progress on the day the sampler visited the centre. The sample unit was also cut at a short fixed distance from the boundary of the field. Again the small plot size which he adopted for the experiments must have contributed to an appreciable over-estimation of yield. Nevertheless, as an example of a sample survey carried out on statistical basis in the days when the role of randomisation in field designs was just beginning to be known, it was an enterprising piece of work.

3.22. The next advance in the problem of estimation of crop yields by random sample survey came from Mahalanobis (4, 5, 6). He started with an experiment on jute in Bengal in 1939, harvesting plots of various sizes ranging from 5.5 to 66 sq. ft. in 22 randomly selected localities in four districts and gradually extended the survey in the following years to cover all the principal jute growing districts of the province. In 1943-44 he carried out experiments for the estimation of the yield of wheat and gram in Bihar. This was followed by a yield survey on paddy in the same province. A province-wide yield survey on paddy was also carried out in Bengal in 1942-43 and is being continued annually. The main features of his method as gathered from the comprehensive account of the Bihar Crop Survey (5) and other published references are that:

(a) the field work is carried out by ad hoc parties of investigators specially appointed for the purpose;

(b) the sampling is confined to those fields which are ready for harvesting on the date of the investigaror's visit to a place;

(c) sample plots range from 12.5 to 100 sq. ft. and possibly to 200 sq. ft. in size and are marked by portable apparatus specially devised for the purpose; and

(d) the field work is arranged in replicated samples called interpenetrating net work of samples.

An extensive study of the different kinds of errors arising in field work leading to the device of interpenetrating net work of samples and other internal controls, and the explicit formulation of the principle of maximising precision for a given cost in its application to the problem of agricultural surveys, in terms of the cost and the variance functions are the principal contributions of Mahalanobis.

3.23. The next important advance came from Panse and Kalamkar (14, 15, 16). Finding that in spite of the admittedly defective nature of official yield statistics, random sampling method had not been taken up by the provinces, they brought an altogether different approach on the problem. They argued that if an objective method of crop estimation was to be successfully introduced in India as an annual feature, the method should be developed in such a manner that it would fit into the existing administrative machinery with the minimum essential changes in the current procedure, and its permanent adoption would not necessitate any heavy additional expenditure. The problem, as they viewed, therefore, was not one of starting any elaborate research on the principles and practice of random sampling but of demonstrating in the first instance to the provincial administrators the practicability, efficiency and economy of the method. The adoption of randomly selected fields for crop cutting experiments was to them a question of convincing the provincial governments that the replacement of the present personal selection of fields by random sampling was both essential and practicable. The number of crop cutting experiments to be carried out and their distribution as also the size of sampling units, however, required to be determined by experimentation.

3.24. The first random sample survey in the temporarily settled provinces to be undertaken with these objectives in view was carried out on cotton in Akola district of the C. P. and Berar (14). The results of this survey showed that the frame work of the Revenue Administration in the temporarily settled provinces lent itself excellently to the application of random sampling method for the estimation of crop yields. Tehsils which form relatively homogeneous and compact divisions of the district were chosen as the strata ; within a tehsil a village was chosen as a unit of sampling; within a village a field was the sub-unit and within a field a plot of 1/10th of an acre was the ultimate unit of sampling. The conclusion of the survey was that by sampling about 70 villages distributed in proportion to the area under cotton in the different tehsils by sampling 3 to 4 fields in each selected village and by harvesting 1/10th of an acre plot in each selected field, the yield for a district can be estimated with a sampling error approaching 5%. The survey was extended to two districts in 1943-44 and to the whole cotton tract in 1944-45 and is since carried out annually. The principal modification in the original design in extending the survey to provincewide scale as an annual feature was the use of revenue inspector's circles as the strata in place of tehsils. This change was made principally on the ground of administrative convenience to ensure even distribution of work among the Revenue Inspectors to whom the work was entrusted. The number of villages allocated varied from 55 to 65 in the principal cotton growing districts and from 30 to 33 in the remaining districts. The yield estimates of principal districts are determined with sampling errors ranging from 5 to 7% and those for the province with error approaching 2%.

3.3 *Surveys by the Indian Council of griculturul Research*

3.31. The first surveys on cereals on full provincial scale using the method based on these results were carried out in 1943-44 in the Punjab, U.P. and Orissa. This was the beginning of the rapid and extensive adoption of the random sampling method all over the country. By 1945, the surveys were extended to cover the principal wheat belt comprising the Punjab, Sind, NWFP, U.P. and C.P. and Berar and in the following year to cover the principal paddy belt comprising Madras, Bombay, C.P., U.P., Bihar and Orissa. The principal development of these surveys was the appointment of full-fledged agricultural statisticians in the provinces to take over this work as an annual feature in place of the current procedure of crop estimation. These appointments in their turn led to a further extension of the scope of these surveys to cover more and more crops. In Bombay Province, crop cutting experiments by the random sampling method are carried out as an annual feature on as many as six crops, wheat, paddy, Jowar (khariff), jowar (rabi), bajra, cotton and pilot surveys are in progress on maize, kodra, tobacco, groundnut, ragi and gram, for investigating the possibility of extending these on a full provincial scale. In the C.P. and Berar, the crops included are wheat, paddy, jowar and cotton. In Bihar experiments are in progress on wheat, paddy, gram, arhar and masur. And appropriately enough, with the renewed drive for increased production of food grain crops and the consequent need for accurately knowing the production of food grains, the Government of India have given a further impetus by approving a five-year scheme for the extension of these experiments to all principal crops in the country including States and State Unions.

3.32. The design adopted in these surveys is stratified multi-stage random sampling. The talukas or the Revenue Inspector's circles into which a district is divided constitute the strata. From each of these a certain number of villages are randomly selected approximately in proportion to the area under the crop in the stratum. In each selected village, three fields (sometimes two) are selected at random out of all the fields sown with the crop and in each selected field a plot of the size usually adopted in official crop cutting experiments is located at random. The final experiment consists in harvesting the crop from the plots so marked and threshing, winnowing and weighing the produce thereform immediately afterwards. Yield of grain from one experimental plot constitutes a single observation for the sample. Allowance for the moisture contained in the produce at the harvesting stage is made on the basis of special experiments conducted for the purpose on a sub-sample of the observations. The experiments are carried out and supervised by the provincial staff of the Departments of Agriculture and/or Revenue. Training classes are conducted annually for the field staff in order to ensure efficient work. The experiments are also supervised periodically by the statistical staff at the provincial headquarters and the Centre. In the five-year scheme additional supervision from the Centre based on the principle of random sampling has been provided.

3.33. The sampling fraction adopted in the surveys varies from five parts in a million to twenty, the variation among other things being brought about by limitations of the staff available in the various strata. The precision attained in the surveys in the various provinces has naturally depended upon the size of the sample but has been on the whole highly satisfactory. For the major districts the yield estimates have been determined with a sampling error approaching 6 or 7% while those for the province as a whole with errors varying from 1 to 4 percent. Before passing on to the other uses of sampling in agricultural statistics, we shall in what follows examine the efficiency of the various technical and organisational aspects of the design so successfully adopted in the yield surveys. We shall, however confine the discussion, owing to the limitation of space, to only the more important features of the design.

3.4 *Estimation of the Mean and its Sampling Error*

3.41. Suppose the population is made up of t strata and we sample n_j units from the j^{th} stratum and further sample m_{jk} sub-units from each of the selected units in the j^{th} stratum.

Let

x_{jkl} be the value of the character for the l^{th} sub-unit of the k^{th} unit of the j^{th} stratum

$\bar{x}_{jk.}$ the true mean of the k^{th} unit of the j^{th} stratum,

$\bar{x}_{jk(m_{jk})}$ the corresponding sample mean, so that

$$\bar{x}_{jk\,(m_{jk})}=\frac{1}{m_{jk}}\sum_{l=1}^{m_{jk}} x_{jkl}$$

$\bar{x}_{j..}$ the true mean of the j^{th} stratum,

$\bar{x}_{j(n_j,\,m_{jk})}$ the corresponding sample mean, so that

$$\bar{x}_{j(n_j,m_{jk})}=\frac{1}{n_j}\sum_{k=1}^{n_j}\bar{x}_{jk(m_{jk})}$$

$\bar{x}_{...}$ the population mean, and

$\bar{x}_{(t,n_j,m_{jk})}$ the corresponding sample estimate, so that

$$\bar{x}_{(t,n_j,m_{jk})}=\sum_{j=1}^{t} W_j\ \bar{x}_{j(n_j,m_{jk})}$$

where W_j is proportional to the size of the j^{th} stratum.

3.42. It is known that when the number of sub-units sampled from each selected unit is constant, say m, the variance of the sample mean is given by

$$V(\bar{x}_{nm})=\sum_{j=1}^{t}\frac{W_j^2}{n_j}\left(\sigma^2_{(sv)j}+\frac{\sigma^2_{(vf)j}}{m}\right) \tag{1}$$

where $\sigma^2_{(sv)j}$ and $\sigma^2_{(vf)j}$ denote the true variances between units (villages) and between sub-units (fields) within units in the j^{th} stratum, the suffixes s, v and f standing for the stratum, village and field respectively. For a finite population of N units with N_j units in the j^{th} stratum and M_j sub-units in each unit, the variance is given by

$$V(\bar{x}_{nm})=\sum_{j=1}^{t}\sigma^2_{(sv)j}W_j^2\left(\frac{1}{n}-\frac{1}{N}\right)+\sum_{j=1}^{t}\sigma^2_{(vf)j}\ W_j^2\left(\frac{1}{n_jm}-\frac{1}{N_j\,M_j}\right) \tag{2}$$

where $M_j\sigma^2_{(sv)j}+\sigma^2_{(vf)j}$ and $\sigma^2_{(vf)j}$ are now defined as the population mean squares between units (villages) and between sub-units within units (fields within villages) in the j^{th} stratum given by

$$M_j\sigma^2_{(sv)j}+\sigma^2_{(vf)j}=\frac{M_j\sum\limits_{k=1}^{N_j}(\bar{x}_{jk.}-\bar{x}_{j..})^2}{N_j-1} \tag{3}$$

$$\sigma^2_{(vf)j}=\frac{\sum\limits_{k=1}^{N_j}\sum\limits_{l=1}^{M_j}(x_{jkl}-\bar{x}_{jk.})^2}{N_j\,(M_j-1)} \tag{4}$$

In crop surveys where W_j would appropriately denote the proportion of the area under the crop in the j^{th} stratum and where the number of fields M_j is large as compared with the number sampled from a village, equation (2) will be

$$V(\bar{x}_{nm}) = \sum_{j=1}^{t} \sigma^2_{(sv)j} W_j^2 \left(\frac{1}{n_j} - \frac{1}{N_j} \right) + \sum_{j=1}^{t} \sigma^2_{(vf)j} W_j^2 \frac{1}{n_j m} \tag{5}$$

the estimates of $\sigma^2_{(sv)j}$ and $\sigma^2_{(vf)j}$ being provided by

$$\sigma^2_{(\ v)j} = \frac{S^2_{(sv)j} - S^2_{(vf)j}}{m} \tag{6}$$

and $$\hat{\sigma}^2_{(vf)j} = S^2_{(vf)j} \tag{7}$$

$S^2_{(sv)j}$ and $S^2_{(vf)j}$ denoting the mean squares between villages and between fields within villages in the analysis of the variance of the sample plots.

3.43. Although it is usually provided that the number of sub-units to be sampled from each selected unit should be constant, this is not always practicable particularly in yield surveys. The form of the best unbiased linear estimate of the true mean for a stratum is not apparent in this case. The weighted mean is given by

$$\frac{\sum\limits_{k=1}^{n_j} m_{jk} \bar{x}_{jk(m_{jk})}}{\sum\limits_{k=1}^{n_j} m_{jk}}.$$

as also the unweighted mean $\frac{1}{n_j} \sum\limits_{k=1}^{n_j} \bar{x}_{jk(m_{jk})}$ provide unbiased estimates of $\bar{x}_j$..

but it will be presently shown that their relative efficiency depends on the relative magnitude of the true variances between and within units. For it is easy to see that whereas the sampling variance of the weighted mean is given by

$$\sigma^2_{(sv)j} \frac{\sum\limits_{k=1}^{n_j} m_{jk}^2}{m_0^2} + \frac{\sigma^2_{(vf)j}}{m_0} \tag{8}$$

where $$m_0 = \sum_{k=1}^{n_j} m_{jk}$$

that of the unweighted mean is

$$\frac{\sigma^2_{(sv)j}}{n_j} + \frac{\sigma^2_{(vf)j}}{n_j^2} \sum_{k=1}^{n_j} \frac{1}{m_{jk}} \tag{9}$$

The differenc between (8) and (9) is not always of the same sign. In fact the unweighted mean will be a more efficient estimate than the weighted mean if

$$\frac{\sigma^2_{(sv)j}}{\sigma^2_{(vf)j}} > \frac{\dfrac{\sum\limits_{k=1}^{n_j} \dfrac{1}{m_{jk}}}{n_j^2} - \dfrac{1}{m_0}}{\dfrac{\sum\limits_{k=1}^{n_j} m_{jk}}{m_0^2} - \dfrac{1}{n_j}}$$

This inequality can be written as

$$\frac{\sigma^2_{(sv)j}}{\sigma^2_{(vf)j}} > \frac{\bar{a}_j \left(\dfrac{\bar{a}_j}{\bar{h}_j} - 1\right)}{s_j^2}$$

where $\bar{a}_j$ and $\bar{h}_j$ are the arithmetic and harmonic means and s_j^2 the variance of m_{jk}'s. If the deviations of m_{jk}'s from their mean are small the inequality can be written as simply

$$\frac{\sigma^2_{(vf)j}}{\sigma^2_{(sv)j}} \leqslant \bar{a}_j \tag{10}$$

In yield surveys the true variance between fields within villages is about twice the true variance between villages, so that the unweighted mean can be taken to be the more efficient estimate than the weighted mean whenever the number of fields sampled per village is three or more. On the other hand when the number of fields sampled from a village is two or less, the weighted mean must be considered to be the more efficient of the two. It can be shown that the above result is independent of the finite size of the population (26).

As to the sample estimates of $\sigma^2_{(vf)j}$ and $\sigma^2_{(sv)j}$ when m is not constant from unit to unit, it can be shown that the best estimate of $\sigma^2_{(vf)j}$ is still provided by the mean square between fields within villages in the sample but that of $\sigma^2_{(sv)j}$ is now given by

$$\hat{\sigma}^2_{(sv)j} = \frac{S^2_{(sv)j} - S^2_{(vf)j}}{\bar{m}_j}$$

where

$$\bar{m}_j = \frac{1}{n_j - 1} \left\{ \sum_{k=1}^{n_j} m_{jk} - \frac{\sum\limits_{k=1}^{n_j} m_{jk}^2}{\sum\limits_{k=1}^{n_j} m_{jk}} \right\} \tag{11}$$

m_{jk} $(k=1, 2, \ldots n_j)$ denoting the number of fields sampled in the k^{th} sampled village of the j^{th} stratum. A pooled estimate of $\sigma^2_{(sv)}$ for the population will be given by

$$\hat{\sigma}^2_{(sv)} = \frac{S^2_{(sv)} - S^2_{(vf)}}{\bar{m}} \qquad (12)$$

where $\bar{m} = \dfrac{\sum_{j=1}^{t} (n_j - 1)\, \bar{m}_j}{n - 1}$ and $S^2_{(sv)}$ and $S^2_{(vf)}$ denote the pooled mean square in the samples.

3.44. The application of these formulæ to yield surveys implies that every plot in a stratum gets an equal chance of being included in the sample. Actually the units and sub-units being of unequal size, smaller villages and smaller fields get a relatively larger chance of selection per unit area under the crop. There is thus a possibility that the yield estimate may be biased if the yield per acre is associated with the size of village (or field). One can, however, correct for this bias either by selecting units and sub-units with probabilities proportional to their size or by weighting plot yields with the corresponding area of fields in a village and weighting the village means by the corresponding areas under the crop. The results of crop surveys, however, show that errors likely to be produced from this source of bias are trivial and call for no correction in practice. The table reproduced below is typical of these results and show that the errors from this source are negligible as compared with the district sampling errors which as stated earlier vary from 5 to 7 percent for major districts.(20)

TABLE 1

WHEAT SURVEY—EAST PUNJAB, 1943-44.

District	Yield in maunds per acre	
	Uncorrected	Corrected
1. Amritsar	12.50	12.65
2. Gurdaspur	10.07	10.47
3. Jullunder	10.20	10.71
4. Hoshiarpur	9.77	9.67
5. Ludhiana	15.16	15.14
6. Ferozepur	12.78	13.00
7. Ambala	10.38	9.96
8. Karnal	10.20	10.55
9. Hissar	13.25	13.88
10. Rohtak	12.20	13.12
11. Gurgaon	9.31	9.14
12. PROVINCE	11.18	11.26

3.45. Similarly in locating a plot at random within a field, the central portion of the selected field will be relatively over-sampled as compared with the surrounding area and may give rise to bias if the yield is correlated with the position of the plot in the field. One can correct for this sampling bias too by means of suitable correction factors evolved for the purpose but the results of crop-surveys have again shown that the errors likely to be produced from this source are trivial. The possible influence of this source of bias can be examined in other ways also such as by tabulating the frequency distribution of the plot yields according to the relative position of the plots in the field. The table given below is typical of the results of crop surveys; column 1 shows the relative position of the plot defined by the quotient of the random number of the starting point of the plot by the length of the field minus the length of the plot ; column 2 shows the number of plots having the relative position as defined in column 1 and column 3 shows the average yield per plot, columns 4 and 5 give the same figures when the relative position is defined along the breadth of the field. It will be seen that there is hardly any association between the average yield and the relative position of the plot in the field which can produce errors comparable with sampling errors. Incidentally the distribution of number of plots shows that the location of the starting point of the plot was genuinely random as expected.

TABLE 2

PADDY SURVEY—MADRAS, 1946-47.

Relative position of the plot	Length		Breadth	
	No. of plots.	Av. yield in oz/plot.	No. of plots.	Av. yield in oz/plot.
0–.1	215	248.8	249	243.7
.1–.2	220	249.4	227	242.2
.2–.3	197	248.6	214	237.0
.3–.4	213	233.5	199	262.6
.4–.5	238	253.7	234	233.2
.5–.6	207	260.4	198	253.1
.6–.7	192	247.5	178	267.6
.7–.8	208	254.9	199	245.3
.8–.9	185	234.2	196	261.1
.9–1.0	201	253.4	182	248.4
Total ..	2,076	248.6	2,076	248.6

3.5. *Allocation of Sampling Units between and within Strata*

3.51. The formulæ given in the previous section have to be supplemented by considerations of cost before using them for obtaining guidance in the optimum allocation of sampling units. When experiments are carried out by the departmental staff in the course of their normal duties, each member of the staff working within his own jurisdiction, the principal item of cost will usually be on labour for harvesting, threshing and cleaning of produce. The expenditure on travelling between villages within circles will usually be negligible under these conditions. Whatever travelling is required, is undertaken as part of the normal touring of the field staff, who are expected to tour about three weeks in a month and cannot possibly undertake more touring merely because additional funds are made available. Equally, the expenditure on statistical analysis connot be charged to the cost of a specific survey when the departmental statistician is available to carry it out as part of his normal functions. At best the expenditure on travelling for supervision incurred by the statistical staff can be charged to the survey but this will usually be small as compared with the expenditure on labour for processing of produce. The contingent expenditure for the survey such as stationery, stamps etc. will vary with the number of experiments. The major part of the total expenditure on a survey when it is planned as an annual feature and carried out by the local departmental staff in the course of their duties will, therefore, roughly vary with the total number of experiments planned as may be seen from the following typical budget for Central Provinces for paddy during 1949-50.

		Rs.
1.	Labour charges for harvesting etc. @ Rs. 2/- per plot (1232 plots)	2464
2.	Stationery, stamps and other contingencies	500
3.	Provision for replacement charges of experimental equipment	500
	Total estimated expenditure	Rs. 3464

Without, therefore, significantly increasing the sampling error by departing from the optimum values, the problem of optimim allocation between strata can be considered as the problem of minimising the sampling variance for a fixed total number of sampling units. Necessarily the principle of minimising the sampling variance for a given number of sampling units will be applied separately to each district because the districts will also be important though subsidiary domains of study.

3.52. The sampling variance of a district mean yield will be given by

$$\sum_{j=1}^{t} \sigma^2_{(sv)j} \frac{A_j^2}{A^2} \left(\frac{1}{n_j} - \frac{1}{N_j}\right) + \sum_{j=1}^{t} \sigma^2_{(vf)j} \frac{A_j^2}{A^2} \frac{1}{n_j m}$$

For a given number of sampling units for the district this is minimised when

$$n_j \propto A_j \sqrt{\sigma^2_{(sv)j} + \frac{\sigma^2_{(vf)j}}{m}} \tag{13}$$

In general, estimates of $\sigma^2_{(sv)j}$ and $\sigma^2_{(vf)j}$ based on even a moderately small sample will improve the allocation (19) but for a stratum of the size of a Revenue Inspector's circle containing hardly 2 to 4 villages in the sample the values will not be sufficiently accurately known. The results of crop surveys show that these values will usually not differ significantly for different strata *within* a district. The distribution of units among the different strata within a district directly in proportion to the area under the crop in the strata and subject to the condition of being whole numbers should, therefore, give a sufficiently good allocation without significantly increasing the cost of the survey or the sampling error of the estimated mean. It is worth noting that the optimum allocation of the sample is independent of N_j.

3.53. The distribution of experiments between villages, fields and plots of a stratum similarly calls for making effective use of the available resources. Clearly the estimated yield for a stratum will have maximum precision when experiments are distributed at the rate of one per village. Equally there are other considerations which counsel reduction in the number of villages by increasing the number of experiments within a village. The foremost of these arises from the need to ensure that the visit of the field staff to a village selected for experiments is fully utilised. The limited period available for harvesting, the poor communications between villages and the fact that the field staff have to do the work in the course of their normal duties all suggest the need for restricting the number of villages by increasing the number of experiments within each. The extent to which the number of experiments within a village can be profitably increased at the expense of the number of villages is seen from the following table showing the number of villages required for a given number of fields per village and plots per field for estimating the mean yield of irrigated wheat with 5 per cent sampling error. Since the results relate to the sampling of irrigated wheat only, they cannot be considered as typical of the crop surveys but they serve well to illustrate the principle under consideration.

TABLE 3

WHEAT SURVEY IN MORADABAD DISTRICT, U.P. 1944-45.
(plot size 1/92th acre)

No. of plots per field. / No. of fields per village	1	2	3	4
	Number of villages.			
1	88	74	70	68
2	63	56	54	52
3	54	50	48	47
4	50	46	45	45
5	47	45	44	43
6	46	43	43	42

It will be seen that while the number of villages decreases rather considerably as the number of fields is increased from one to two, there is not any appreciable decrease in the number of villages with further increase in the number of fields. The increase in the number of plots per field has hardly any effect on the number of villages. These results suggest that two fields per village with one plot per field is about the optimum distribution within a stratum.

3.6 *Stratification*

3.61. For province-wide yield surveys, with districts as domains of study, which are to be carried out annually, the method of stratification has to be both administratively convenient and statistically efficient. The former requirement leads to the choice of the revenue inspectors' circles (or talukas) as the strata. In this section we shall examine their efficiency in terms of the relative magnitude of the variances of the district estimate (a) with revenue inspectors' circles (or talukas) as the strata and (b) without strata.

3.62. An examination of the equation (1) for the variance of the mean in a sub-sampling design will show that for estimating the variance (b) all that is needed is an estimate of the quantity σ^2_{dv} representing the true variance between villages within district. It follows that the gain due to stratification for any district is simply the percentage increase of the variance given by

$$V\{\bar{x}_{(nm)}\} = \frac{\sigma^2_{dv}}{n} + \frac{\sigma^2_{vf}}{nm} \tag{14}$$

over the variance given by (1). The effect of varying the numbers of villages and fields per village on the gains due to stratification is also easily calculated by substituting in these formulæ the desired values of n and m. Since $\sigma^2_{(vf)j}$ and $\sigma^2_{(sv)j}$ can be estimated from (6) and (7) the problem thus reduces to the estimation of σ^2_{dv} defined by

$$\sigma^2_{dv} = E(\bar{x}_{jk\cdot} - \bar{x}_{\cdots})^2 \tag{15}$$

We shall express the difference $\bar{x}_{jk\cdot} - \bar{x}_{\cdots}$ as

$$\bar{x}_{jk\cdot} - \bar{x}_{\cdots} = \bar{x}_{jk\cdot} - \bar{x}_{j\cdot\cdot} + \bar{x}_{j\cdot\cdot} - \bar{x}_{\cdots} \tag{16}$$

Squaring and taking expectations, we have

$$E(\bar{x}_{jk\cdot} - \bar{x}_{\cdots})^2 = \sum_{j=1}^{t} W_j \sigma^2_{(sv)j} + \sum_{j=1}^{t} W_j \bar{x}_{j\cdot\cdot}^2 - \bar{x}^2_{\cdots} \tag{17}$$

Let

$$\left.\begin{aligned} x_{jkl} - \bar{x}_{jk\cdot} &= \epsilon_{jkl} \\ \bar{x}_{jk\cdot} - \bar{x}_{j\cdot\cdot} &= \bar{\varepsilon}_{jk\cdot} \\ \text{and} \quad \frac{1}{n_j}\sum_{k=1}^{n_j} \bar{\varepsilon}_{jk\cdot} &= \bar{\varepsilon}_{j(n_j)\cdot} \end{aligned}\right\} \tag{18}$$

so that

$$\frac{1}{n_j}\sum_{k=1}^{n_j} \bar{x}_{jk\cdot} = \bar{\varepsilon}_{j(n_j)\cdot} + \bar{x}_{j\cdot\cdot} \tag{19}$$

Squaring and taking the expected values in (19) and remembering that

$$E(\bar{\varepsilon}_j{}^2_{(n_j)\cdot}) = \frac{\sigma^2_{(sv)j}}{n_j}, \tag{20}$$

we have

$$E\left\{\sum_{j=1}^{t} W_j \bar{x}_j{}^2_{(n_j)\cdot}\right\} = \sum_{j=1}^{t} W_j \bar{x}_{j\cdot\cdot}^2 + \sum_{j=1}^{t} \frac{W_j}{n_j} \sigma^2_{(sv)j} \tag{21}$$

From (19) we also have

$$\sum_{j=1}^{t} W_j \bar{x}_{j(n_j)\cdot} = \sum_{j=1}^{t} W_j \bar{\varepsilon}_{j(n_j)\cdot} + \sum_{j=1}^{t} W_j \bar{x}_{j\cdot\cdot}$$

whence, squaring and taking expected values on both sides and denoting

$\sum_{j=1}^{t} W_j \bar{x}_{j(n_j)\cdot}$ by $\bar{x}_{(n)\cdot}$ and $\sum_{j=1}^{t} W_j \bar{x}_{j\cdot\cdot}$ by $\bar{x}_{\cdot\cdot\cdot}$

$$E\left\{\bar{x}^2_{(n)\cdot}\right\} = \sum_{j=1}^{t} \frac{W_j^2}{n_j} \sigma^2_{(sv)j} + \bar{x}^2_{\cdot\cdot\cdot} \qquad (22)$$

From (21) and (22) we obtain

$$\sum_{j=1}^{t} W_j \bar{x}_j^2{}_{\cdot\cdot} - \bar{x}^2_{\cdot\cdot\cdot} = E\left\{\sum_{j=1}^{t} W_j \bar{x}_j^2{}_{(n_j)\cdot} - \bar{x}^2_{(n)\cdot}\right\} - \sum_{j=1}^{t} \frac{W_j}{n_j} \sigma^2_{(sv)j}$$

$$+ \sum_{j=1}^{t} \frac{W_j^2}{n_j} \sigma^2_{(sv)j} \qquad (23)$$

Substituting in (17), we have

$$\sigma^2_{dv} = \sum_{j=1}^{t} \left\{W_j - \frac{W_j}{n_j} + \frac{W_j^2}{n_j}\right\} \sigma^2_{(sv)j} + E\left\{\sum_{j=1}^{t} W_j \bar{x}_j^2{}_{(n_j)} - \bar{x}^2_{(n)\cdot}\right\} \qquad (24)$$

Now taking the mean over m_{jk} fields in the k^{th} village of the j^{th} stratum in equation (1) in (18), we have

$$\bar{x}_{jk(m_{jk})} = \bar{\varepsilon}_{jk(m_{jk})} + \bar{x}_{jk\cdot} \qquad (25)$$

Summing (25) over a given n_j villages in the j^{th} stratum and taking the mean we get

$$\bar{x}_{j(n_j m_{jk})} = \frac{1}{n_j} \sum_{k=1}^{t} \bar{\varepsilon}_{jk(m_{jk})} + \bar{x}_{j(n_j)\cdot} \qquad (26)$$

Whence, squaring and taking expectations on both sides, multiplying by W_j and summing over all the t strata we have

$$\sum_{j=1}^{t} W_j \bar{x}^2_{j(n_j)\cdot} = E\left\{\sum_{j=1}^{t} W_j \bar{x}^2_{j(n_j, m_{jk})}\right\} - \sum_{k=1}^{n_j} \frac{W_j}{n_j \bar{h}_j} \sigma^2_{(vf)j} \qquad (27)$$

where $\bar{h}_j$ is the harmonic mean of m_{jk}'s.
From (26) we also obtain

$$\sum_{j=1}^{t} W_j \bar{x}_{j(n_j, m_{jk})} = \sum_{k=1}^{n_j} W_j \bar{\varepsilon}_{j(n_j, m_{jk})} + \sum_{j=1}^{t} W_j \bar{x}_{j(n_j)\cdot}$$

or

$$\bar{x}_{(t, n_j, m_{jk})} = \sum_{j=1}^{t} W_j \bar{\varepsilon}_{j(n_j, m_{jk})} + \bar{x}_{(n)\cdot} \qquad (28)$$

Squaring and taking expectations for a fixed n

$$\bar{x}^2_{(n)\cdot} = \mathrm{E}\left\{ \bar{x}^2_{(t, n_j, m_{jk})} \right\} - \sum_{j=1}^{t} \frac{W_j^2}{n_j} \frac{\sigma^2_{(vf)j}}{\bar{h}_j} \tag{29}$$

From (27) and (29) we have

$$\sum_{j=1}^{t} W_j \bar{x}^2_{j(n_j)\cdot} - \bar{x}^2_{n\cdot} = \mathrm{E}\left\{ \sum_{j=1}^{t} W_j\, \bar{x}^2_{(n_j, m_{jk})} - \bar{x}^2_{(t, n_j, m_{jk})} \right\} - \sum_{j=1}^{t} \frac{W_j}{n_j \bar{h}_j} \sigma^2_{(vf)j}$$

$$+ \sum_{j=1}^{t} \frac{W^2_j}{n_j} \frac{\sigma^2_{(vf)j}}{\bar{h}_j} \tag{30}$$

Substituting the result from (30) in (24) we have

$$\hat{\sigma}^2_{dv} = \sum_{j=1}^{t} \left(W_j - \frac{W_j}{n_j} + \frac{W_j^2}{n_j} \right) \sigma^2_{(sv)j} - \sum_{j=1}^{t} \left(\frac{W_j}{n_j}\,_j - \frac{W_j^2}{n_j\, h_j} \right) \sigma^2_{(vf)j}$$

$$+ \sum_{j=1}^{t} W_j\, \bar{x}_j^2{}_{(n_j, m_{jk})} - \bar{x}^2_{(t, n_j, m_{jk})} \tag{31}$$

Whence on substituting in (14), we obtain an estimate of the variance of the district mean appropriate for the method of sampling villages directly from the district without stratification. On pooling the results for the distritcs we get the gain in precision resulting from stratification for the province as a whole.

3.63. Results given below are typical of the gains in precision resulting from stratification. Row 1 of the table 4 gives the sampling variance of the observed mean, row 2 gives the estimated variance of the mean if villages had been selected directly from each district i.e. without strata within dis-

TABLE 4

PADDY SURVEY IN MADRAS, 1946-47, 1947-48

FIRST CROP

Variance	1946-47			1947-48		
	No. of fields			No. of fields		
	2	3	4	2	3	4
1) Talukas as strata (actual)	27.6	24.0	22.2	32.7	27.4	24.7
2) Districts as strata	31.5	28.1	26.4	47.7	42.7	40.2
3) % gain	14.0	17.1	19.1	45.8	56.2	63.0
4) Talukas as strata ($n_j \propto A_j$ within districts)	25.5	22.1	20.4	30.4	25.4	22.9
5) % gain	23.4	27.0	29.2	56.9	68.0	75.4

SECOND CROP

Variance	1946-47			1947-48		
	2	3	4	2	3	4
1) Talukas as strata (actual)	28.8	24.9	22.9	59.6	53.2	50.1
2) Districts as strata	34.2	30.8	29.1	70.3	64.8	62.1
3) % gain	18.6	23.6	26.7	18.0	21.8	24.0
4) Talukas as strata $n_j \propto A_j$ within districts	25.0	21.6	19.9	51.6	46.1	43.4
5) % gain	36.8	42.5	46.2	36.3	40.6	43.1

tricts, row 3 gives the percentage gain in precision, row 4 gives the estimated variance had villages been distributed in proportion to the area under paddy in each taluka of the district and row 5 the corresponding gain in precision. The effect of varying m is also brought out in the table. The table shows that while the gains actually made are of the order of 20% (except in one season when it reaches over 40%) there is considerable scope for further increasing these gains by distributing villages in proportion to the acreage under paddy in the different strata.

Studies undertaken on the relative efficiency of revenue inspectors' circles and tehsils as the strata show that the precision is improved by using circles in place of taluka as the strata but the gain is not appreciable.

3.64 The formulæ derived above are general formulae for estimating gains due to stratification in a sub-sampling design. Two particular cases of the formulae are worth noting :

(*a*) *No sub-sampling*

The appropriate expression for $\hat{\sigma}^2_{dv}$ on a unit basis is derived from (31) by replacing $\bar{h}_j$ by unity. This is the expression given by Yates (28).

(*b*) *Sub-sampling when* $m_{jk}=m$, $n_j \propto W_j$, $\sigma^2_{(sv)j}=\sigma^2_{(sv)}$ and $\sigma^2_{(vf)j}=\sigma^2_{(vf)}$

Then $$\hat{\sigma}^2_{dv} = \hat{\sigma}^2_{sv} + \frac{t-1}{t}\,\hat{\sigma}^2_{ds}$$

so that the gain in precision when m fields are sampled per village is simply

$$\frac{t-1}{t}\,\hat{\sigma}^2_{ds} \Bigg/ \hat{\sigma}^2_{sv} + \frac{\hat{\sigma}^2_{vf}}{m}$$

This expression was first given by Cochran (1) and usually overestimates gains due to stratification. The exact expression of $\hat{\sigma}^2_{dv}$ when N_j is finite is slightly different from that in (31) and is given elsewhere by the author (26).

3.7 *Size of Sampling unit*

3.71. As mentioned earlier, the choice of sampling units whether in the first, second or ultimate stages of sampling has to be made on grounds of both administrative convenience and statistical efficiency. The former consideration requires that the sampling units should be natural units or natural groups of such units. The possible alternatives in the first stage of sampling are, therefore, a village and a patwari circle. A field is the natural choice in the second stage of sampling, while within a field the unit has to be necessarily an artificial one but even here, as will be presently shown, there is an advantage in continuing the current official plot size.

3.72. The relative efficiency of using a village and patwari circle as the units of sampling in the first stage with a field (or plot) as the sub-unit can be readily determined by the approach indicated in the previous section. For it is easy to see that the variance of the sample mean based on n' patwari circles and m' fields is given by

$$\sigma^2_{sc}\left(\frac{1}{n'}-\frac{1}{N'}\right)+\sigma^2_{cf}\left(\frac{1}{n'\,m'}\right) \qquad (33)$$

while that based on n' villages and m' fields by

$$\sigma^2_{sv}\left(\frac{1}{n'}-\frac{1}{N}\right)+\sigma^2_{vf}\,\frac{1}{n'\,m'} \tag{34}$$

N′ and N denoting the numbers of patwari circles and villages in the stratum. The gain in precision using a patwari circle as unit in place of village is, therefore, given by the ratio of (34) to (33).

3.73. Results of the yield surveys carried out in small tracts like Delhi Province with patwari circles as the strata and a village, field and plot as the successive units of sampling within patwari circles enable us to judge the relative efficiency of a patwari circle and village as units of sampling in large-scale yield surveys. These are set out in the table below for $n'=5,10,20$ and $m'=2$. It will be seen from the table that the gain in precision resulting from the use of patwari circle as a unit of sampling increases as n' increases being about 20% when $n'=5$, which is about the number usually selected per stratum in large scale yield surveys. Whether this gain will compensate the additional labour involved in sampling fields directly from the circles is a question which deserves to be studied further.

TABLE 5

Wheat Survey—Delhi Province, 1946–49

	1946-47			1947-48			1948-49		
n'	5	10	20	5	10	20	5	10	20
Variance with village as the unit	157.1	77.7	38.0	151.6	75.1	36.9	160.3	84.5	41.5
Variance with circle as the unit	124.8	60.2	27.9	138.5	67.4	31.9	130.0	63.1	30.0
% gain	25.9	29.0	36.2	9.4	11.4	15.7	23.7	33.7	38.5
ρ_1	0.56			0.42			0.39		
ρ_2	0.36			0.27			0.25		

3.74. An alternative approach for studying the relative efficiency of different sizes of sampling units, which in some ways appears to be more instructive, is due to Hansen and Hurwitz (10, 11). It is based on the concept of intra-class correlation between sub-units of a unit of sampling. If ρ_1 denotes the intra-class correlation between sub-units in a village and ρ_2 that between sub-units in a circle, then neglecting terms in 1/M

$$\rho_1=\frac{\frac{N-1}{N}\,\sigma^2_{sv}}{\sigma_1^{\,2}} \tag{35}$$

where

$$\sigma_1^{\,2}\simeq\sigma^2=\frac{N-1}{N}\,\sigma^2_{sv}+\sigma^2_{vf}$$

and

$$\frac{N'-1}{N'\;\rho_2}\,\sigma_{sc}^{\,2} \tag{36}$$

where $$\sigma_2^2 \backsimeq \sigma^2 = \frac{N'-1}{N'} \sigma^2_{sc} + \sigma^2_{cf}$$

Substituting these in (33) and (34) we have

$$V(\bar{x}_{n}{'}_{m}{'}) = \frac{\sigma^2}{n'm'} \left\{ 1 + \rho_1 \left(\frac{N'-n}{N'-1} \cdot m'-1 \right) \right\} \tag{37}$$

$$V(\bar{x}_{n}{'}_{m}{'}) = \frac{\sigma^2}{n'm'} \left\{ 1 + \rho_2 \left(\frac{N'-n'}{N'-1} \cdot m'-1 \right) \right\} \tag{38}$$

The first factor in the above formulae clearly represents the variance of the mean based on $n'm'$ sub-units sampled at random directly from the population, while the second factor measures the contribution to the sampling variance of cluster sampling, the relative efficiency of the two units being given by the ratio of the two variances. The values of ρ_1 and ρ_2 for Delhi data are shown in the Table above.

3.75 The size of plot to be adopted in yield surveys has been a subject of extensive investigations by the Indian Council of Agricultural Research. As stated in Section 3.2, the plot size adopted in the earlier attempts to introduce random sampling in India was small, being of the order of 1/2000th of an acre. The plot size used in similar investigations in U.S.A. and U.K. was even smaller. As against this practice the plot size adopted by the Council was usually the official one in vogue in the provinces, ranging from 1/160th of an acre on paddy in Orissa to 1/20th of an acre on wheat in the Punjab. This was in keeping with the policy of effecting only the minimum essential changes in the official procedure. In view of the wide divergence in usage, however, opportunity was taken in the course of the crop surveys to carry out detailed investigations on the point. The results of these investigations are too well known to need any repetition (22, 23, 24 25). They have shown that small size plots, whose chief merit is that they can be marked by a portable frame and their produce can be handled by the experimenter himself without the help of hired labour, are liable to give biased yield estimates. The risk is particularly serious where, as in this country, crops are unevenly shown and experiments have to be carried out by the local departmental staff in the course of their normal duties. In contrast, the results have shown that large plots of the order of 1/80th of an acre or more are free from bias.

3.76. These results have led to some controversy in India on the question of small versus large size plots but this need not concern us here. Those interested may refer to the correspondence in Nature (9, 22, 24, 25). I may, however, refer to one explanation of these results by Yates suggesting that the bias reported is not improbably due to inexperience and the very careless work of the experimenters (28). Yates is here principally concerned with the magnitude of this bias but his explanation must be rejected since in point of fact the field work was carried out under the personal supervision of trained statisticians familiar with crop sampling work. I would only add that since the publication of our results extensive evidence has been collected, notably by Panse and Paithankar which conclusively shows that plots of very small size like those used in U..K. and U..S.A. or employed in earlier crop surveys in India lead to significant over-estimation of yield (13, 18). Any discussion of the magnitude of the bias or its possible causes such as border discrepancies or faulty location is, therefore, a matter of secondary interest. The important point to note is that in recommending a method for adoption in practice especially in cases where the employment of a special agency of trained technicians is out of the question and the experiments have to be carried out in the unevenly sown crops by the local departmental staff in the course of their normal duties, care has to be taken to see that the method is not susceptible to obvious sources of bias in the hands of the agency employing it.

4. OTHER USES OF SAMPLING

4.1. *Area Statistics*

4.11. The method of complete enumeration for obtaining crop acreages has been briefly referred to in Section 2. Given adequate and effective supervision, the method is known to work satisfactorily in practice. The relative merits of this method and that of random sampling have been a subject of some discussion in recent years in India. We have examined this question in great detail (17.) with special reference to the sample surveys for acreage conducted by Mahalanobis (6). We have concluded that random sampling method, at least as has been developed so far in India, cannot be expected to furnish area estimates for all crops and for all important administrative units except at disproportionate cost and effort and cannot, therefore, be a substitute for complete enumeration. At the same time we do not minimise the role of sampling in improving area statistics in other ways. In this section we shall examine the possibility of using the principle of random sampling for improving pre-harvest forecasts of crop acreages and for providing a rational method of supervising patwaris' work.

4.12. The importance of reliable pre-harvest forecasts of acreage for taking decisions on food policy cannot be over-estimated. Unfortunately. however, records of field to field inspection by patwaris which form the basis of area enumeration are not available until after the harvest is over. In their absence the earlier forecasts of acreage are compiled from the probable estimates of acreage furnished by Revenue Inspectors and Tehsildars on the basis of their knowledge of the conditions under which sowings are made and information on other factors gained in the course of their tours. A comparison of the earlier forecasts with the final ones based on field to field inspection reveals wide differences indicating that earlier area forecasts are not reliable. One method of improving the position would be to get the patwaris to finish the Girdawaris in time for the first forecast. This, however, is not practicable because a Patwari is in charge of several villages and has also to attend to a number of other duties. The other alternative is to develop a suitable sampling technique using village, instead of patwari circle, as the sampling unit of enumeration and employing the *same* organisation and method of inspection as followed in preparing the final area forecasts.

4.13. The possibility of using the method of sampling can be studied most easily when data are available for the whole of the population. An opportunity was, therefore, taken of studying the Khasra registers for all the villages in two districts with a view to find out whether a reasonably small sample of villages could be expected to furnish reliable estimates of acreages in the province. A promising method appeared to be the stratified method of random sampling, stratifying the villages according to their size as determined by the agricultural area in the village and allocating the sampling among the different strata in proportion to the product of the number of villages in the stratum and the standard deviation per village of its agricultural area. The results of the study on four principal crops in the Meerut district using different numbers of strata are shown in the table below ;

Number of Strata	No of villages required			
	Wheat	Gram	Maize	Sugarcane
Nil	223(15)	401(24)	377(23)	394(24)
Two	100(6)	181(11)	200(12)	251(15)
Four	68(4)	139(9)	168(10)	218(14)
Five	58(3.5)	128(8)	161(10)	210(13)
Sampling with proby. proportional to size	30(2)	110(7)	125(8)	257(15)

The table shows the number of villages required for estimating the area of wheat, gram, maize and sugarcane with 5% sampling error. The figures in brackets show the numbers of villages expressed as percentage of the total. It will be seen that with 4 strata, only 4% villages are required for estimating the area under wheat with 5% sampling error. The results show that with a sample of about 10% villages, it should be possible to estimate the district acreage under principal crops with sampling errors approaching 5% and the provincial acreages with errors approaching 1%.

4.14. Sampling with probability proportional to the size of a village as measured by its agricultural area is another approach to the problem. The results of the application of this method are shown in the last row of the above table. It will be seen that only 2% villages will be required for estimating the acreage under wheat with 5% error The conclusions in respect of other crops remain more or less unaltered.

4.15. There will of course be some difficulty in applying the results in actual practice for the purpose of improving the accuracy of earlier area forecasts. For, complete enumeration of a village soon after the sowings especially in the rainy season, is always a difficult proposition. Two suggestions offer themselves in this connection. The possibility of getting together cultivators and enquiring from them the names of crops grown on the various plots in their Khasras deserves consideration. The presence of neighbours at such a meeting and the help of detailed maps should ensure accuracy of information. Whatever might have been the reasons in the past for not expecting accurate information from patwaris, they would certainly be not true in the same measure under the changed political conditions of today. Moreover, the information sought has little or no bearing on the revenue to be collected and as such there is no reason to suspect the veracity of the information supplied by the cultivators. The other possibility is to reduce the work in the selected villages by the device of sub-sampling. Without going into a detailed consideration of the question for paucity of space, I shall only add that investigations have shown that, by enumerating only a small fraction of the area in the village, without materially increasing the size of the sample, the provincial acreages can be estimated with reasonable precision.

4.16. The above results also suggest a more rational way of organising the supervision of the work of patwaris by their superiors already provided for under the rules in force. The Land Records Rules for U.P. provide, for instance, that the Supervisor Kanungo should test not less than 7% of the Khasra numbers in each season. Similar rules of supervision exist in other provinces. Without, therefore, having to materially increase the amount of supervision, the results indicate the need of revising the plan of supervision to ensure effective check over patwaris' work.

4.17. Another device in sampling which offers possibilities of forming reliable estimates of pre-harvest forecasts is that of 'identical' samples in consecutive years. Results of the study on two consecutive years' area records for Bajra and Jowar for villages in Haveli taluka in the Poona district given below show the possibility of reliably estimating the change in acreage by enumerating a small number of villages and using the ratio method of estimation on previous years' records. The combination of the device of stratification by size of village with that of 'identical' samples in successive years is found to be even more effective in reducing the size of sample but space does not permit further consideration.

NUMBER OF VILLAGES REQUIRED TO BE SAMPLED FOR ESTIMATING THE CROP ACREAGE WITH 5% SAMPLING ERROR

	Bajra	Jowar
Average per village estimate	102	107
Ratio estimate	28	48

4.2. *Livestock Statistics*

4.21. Results of analysis indicate that for several other agricultural items, the use of village as a unit of sampling is not only administratively convenient but also statistically efficient, provided it is combined with suitable systems of stratification and methods of estimation. Results obtained from the analysis of 1946-47 and 1947-48 data from Haveli taluka for samples stratified by size of village in two categories for estimating the numbers of different livestock are given below. The improvement brought about by the use of the 'ratio' method of estimation using previous years' observations is also shown in the table:—

	Bullocks		Buffaloes	
	Unrestricted	Stratified	Unrestricted	Stratified
Average per village estimate	86	62	79	77
Ratio estimate	67	41	45	42

It will be seen that about 40 villages are required for estimating the total numbers of bullocks and buffaloes in the taluka with sampling error of 5%. The results are tentative being based on studies of one taluka only but they serve to give a good idea of the possibility of estimating the total livestock of different descriptions for a district with a reasonably small sample of villages.

4.22. A number of other small-scale investigations using alternative designs of sampling including sub-sampling, directed towards the examination of the scope for using sampling method for estimating principal agricultural items are in progress in the Indian Council of Agricultural Research. We shall refer here to only one more of these examples concerning the estimation of the total quantity of cattle-yard manure used in fields in a given area. The investigation was carried out in Ajmer-Merwara during 1948-49. The results of the analysis will be found in (27). The analysis indicated that by sampling between 60 to 70 villages per district and making use of the high correlation between the quantity of manure used and the livestock population in the village, the total farm-yard manure for the district could be estimated with about 5 percent sampling error. The use of the regression method of estimation led to a gain of over 60 percent in precision.

4.3. *Grow More Food Statistics*

4.31. Any account of sample surveys in agriculture will be incomplete at the present juncture without a reference to GMF statistics. Though of more immediate concern, GMF statistics stand in greater need of improvement than other agricultural statistics. Large sums of money have been spent on the Campaign but there has been nothing like a serious attempt to scientifically assess its results so far. The GMF. effort is broadly in two directions (a) extension of area under food crops and (b) intensification of cultivation by the use of measures like manures, improved seed and new irrigations. The problem of assessing additional production from the former is straight-forward. It is the latter that presents considerable difficulty and calls for the use of sampling methods. The method at present used for estimating additional production from a GMF measure, say, distribution of Ammonium Sulphate is to assume a certain rate of increase in yield per ton of the fertiliser and multiply it by the total quantity of the fertiliser distributed. The method is open to correction on several scores: (1) the quantity distributed may have found its way to channels unintended. Thus seed may be partially eaten up, manure fed to cattle, diverted to cash crops or applied in doses different from those recommended, (2) the rate of response assumed may not be valid under cultivator's conditions and can hardly be invariant with reference to seasons, and (3) the effect of joint application of more than one GMF measure may well be other than additive. Even the rate of response assumed is empirical and not tested by experimentation on land actually receiving GMF aid. The remedy lies in continuous sample surveys specially designed for the purpose.

4.32. To be put wise about the course of the campaign, however, it is not enough merely to assess the results actually obtained. We also need to know (i) the gains anticipated and (ii) the possible scope for further increase in the anticipated gains. Information on additional production that could have been achieved had all the GMF aid been applied to the intended fields at the prescribed rate and the gains actually made, will reveal the scope for improvement in the operations of the Campaign. An answer to the second question would tell us where and how the limited effort could best be expended. The fact is perhaps not noticed that experimentation of the kind refered to above is very properly 'Operational' research in the field of Agriculture, since it primarily aims at providing the Administration with a quantitative basis for taking immediate decisions regarding the operations under their control. The contribution of Operational research to the success of a campaign has by now come to be well appreciated, although the place which operational research has eventually attained had to be hard won as the story from Great Britain which I am tempted to cite below will show. There was, it seems, some difference of opinion between the Operational research team of the Coastal Command and the Bomber Command during the war. The former, it is said, advised the use of twentyfive additional aircraft than were available for the patrol force with the Bomber Command, when an argument ensued and a Senior Bomber Command Officer enquired whether the war was to be fought with slide rules or with weapons. Matters came to such a pass that a trial had to be actually ordered by the Prime Minister and the result proved, much to the amazement of the Bomber Command, that the slide rule had won. Whether in India, where the food front is officially recognised as a war front, the indifference to the kind of research I mentioned above has been due to a genuine paucity of funds or a lack of appreciation of the importance of Operational research in the field of Food and Agriculture, is difficult to say. The moral is obvious. Research is a small investment yielding rich dividends and is it not well known that when a penny must be spent to see if a pourd is well invested, we must not fight shy of the expense especially if we must need to know how best to utilise the few pounds left in hand?

REFERENCES

1 Cochran, W. G. (1939). J. Amer. Statist. Ass. *34*, 492-510
2 Hubback, J. A. (1927) Imp. Agric. Res. Inst., Pusa, Bull. 166
3 Mahalanobis, P. C. (1940), Sankhya *4*, 511-530
4 ——— (1942), "Presidential Address, Section of Statistics"—Indian Science Congress Baroda.
5 ——— (1944), Roy Soc. Phil., Tans, B, 231, 329-451
6 ——— (1945), Sankhya, *7*, 29-106
7. ——— (1946), J. R. Statist. Soc., *109*, 325-378.
8. ——— (1946), Sankhya, *7*, 269-280
9. ——— (1947), Nature, *158*, 799
10. M H. Hensen & W. N. Hurwitz, (1942), Amer. Statist. Assoc., *37* 89-94.
11. ——— (1943), Annals of Math. Statist. *14*, 333-362.
12. Panse, V. G., (1946) Report on the Scheme for the Improvement of Agricultural Statistics, Manager of Publications, Government of India.
13. ——— (1946), Current Science, *15*, 218-219.
14. Panse, V. G. and Kalamkar, R. J. (1944), Current Science, *13*, 120-124
15. ——— (1944), Current Science, 13, 223-225.
16. ——— (1945), Current Science, *14*, 287-291.
17. Panse, V. G. and Sukhatme, P. V., (1948), Ind. Soc. Agri. Statist. *1*, 34-58.
18. Paithankar, M. N. (Unpublished). Thesis submitted for M.Sc. (Agriculture), Nagpur University.
19. Sukhatme, P. V. (1935), J. R. Statist. Soc., Suppl. *2*, 253-268
20. ———(1946), Report on Crop Cutting Experimental Survey for Estimating the outturn of wheat, Punjab (1943-44), Government of India Press.
21. ——— (1945), Ind.J. Agric. Sci., *15*, 308-318
22. ——— (1946), Nature, *157*, 630
23. ——— (1947), J. Amer. Statist. Ass. *42*, 297-310.
24. ——— (1947), Nature, *158*, 345
25. ——— (1947), Nature, 160— 542
26. ——— (1949), J. Ind. Soc. Agric. Statist., *2*.
27. ——— (1949), Compost Bulletin, *2*, 20-23
28. Yates, F. (1949), "Sampling Methods for Census and Surveys", London, Griffin.

SECTION OF PHYSICS

PRESIDENT: DR. R. N. GHOSH, D.SC., F. AOUST. SOC., F.N.I.

Presidential Address.

ROOM ACOUSTICS AND ULTRASONICS

I wish to express my grateful thanks to you for selecting me to preside over the Physics Section of the Science Congress. It is an honour to the particular branch of Physics viz. Acoustics on which I am going to speak; this small branch of Physics had no important place in the past. With the development of the new tool—the thermionic—valve Acoustics has made a rapid progress in the domain of practical field in recent years. In fact it has tremendous applications to Industry and War as well as to the service of society.

In this particular branch of Physics India's contribution is of fundamental character ; the work on the theory of bowed strings by Sir C. V. Raman will remain a monument to the science of vibrations. The mechanically played violin still form a fascinating branch of study of a group of American scientists led by F.A. Saunders[1]. The study of the different parts of the violin has revealed their characteristics and very soon one will be able to purchase a 'Stradivartone'' from the market—a result of Raman's researches. Raman and Banerji's work on the vibrations of pianoforte strings was followed by a large number of Indian workers among which the name of Late Mr. Das, M. Ghosh and the author may be mentioned who have extended Raman's work for soft and elastic hammers. One of the important contributions to the sound of impact due to spherical balls is due to Dr.S. K. Banerji[2], the present Director General of Meteorology. Coming to investigations of Indian musical instruments, the study of the harmonic character of Tabla as shown by Prof. C. V. Raman[3] still remain problem for the mathematicians to solve.

This in short represents the early history of the contributions of Indian workers to theory of audible vibrations.

In the domain of high frequency sound waves, Raman and Nagendra Nath's[4] contributions have opened a new chapter in the science of ultrasonics. To quote Bergmann "It was a great achievement on the part of Raman and Nagendra Nath when they succeeded in clearing up the greater part of these phenomena" some of which are very complex. The authors assume that the light waves in passing through a medium permeated by ultrasonic waves are not bent or deflected, so that in passing through the compressions and rarefactions of the medium, only the velocity and hence the phase, but not the amplitude of the light waves, is changed. Hence if a plane light wave passes through a plane sound wave at right angles to its direction of propagation, the sound wave acts like a phase grating. Their theory gives the ratio of the intensities of the diffracted light for two orders m and n by

$$\frac{Jm^2\ (a)}{Jn^2\ (a)}, \qquad \text{where } a = \frac{2\pi\Delta\mu L.}{\lambda}$$

where $\Delta\mu$ is the change in the refractive index, L the width of the cell and λ the wave length of the light used. This is in excellent agreement with Bar's observed values.

Raman and Nagendra Nath's work was followed by Dr. S. Parthasarathy[5]. He observed the dependence of the diffraction phenomena upon the vibration of angle of incidence and also noticed that a quartz plate vibrates simultaneously at 5/2 & 7/2 harmonics. His later work consisted in measuring the absorption coefficient in various liquids by measuring the intensities of diffracted lights by an ingeneous method. If I_0 and I be the incident and diffracted light intensities after traversing a thickness x, then

$$\frac{I_0-1}{1} = 1 - \frac{\Theta_1}{\Theta_2} = K\ J_0\, e^{-2\alpha x}$$

where J_0 represents the intensity of sound waves at x=0, and α the absorption coefficient. Taking logarithms we get $\log e^{(1-\Theta_1/\Theta_2)} = \text{const}-2\alpha x$ Dr. Parthasarathy determined α by measuring the ratio of intensities by photographing two orders of spectra, the intensities being computed by photometric estimation of the density of the plate. Another important contribution is due to the Andhra School of Physics led by Dr. S. Bhagvatam an account of which is given in the Presidential address of (1946) Bangalore Session of Science Congress. The Wedge method of continuously varying frequency enabled the workers to determine the elastic constants of crystals. Work in this direction is being carried on by Dr. Bishambhar Dayal of Allahabad University.

MODERN ACOUSTICS

Modern acoustics to-day has drifted more towards applications, and the theoretical work has to be directed towards that end. It has to serve two-fold purpose. It has to satisfy the public and also the industry. We shall discuss how physicists have been able to serve the cause of science and the public both in their own pursuit after truth.

One of the most important application in the practical field is the study of room acoustics and its correction. After the pioneer work of W. C. Sabine (1900) the subject of room acoustics had become a part of room engineering, and Sabine's reverberation formula

$$t = \frac{\cdot 05V}{\Sigma\alpha S}$$

was used indiscriminately for all kinds of acoustic designs and corrections. Experimental evidence accumulated, however, to show that it is very necessary to use Sabine's formula with care and caution so that Sabine's conditions are satisfied.

Sabine's formula was based upon the statistical behaviour of the room. If we assume a sound pulse to originate from the source it will be multiply reflected from the walls, and therefore when the mean free path of travel of different sound pulses is determined by the statistical method, it comes out to be 4V/S, while Sabine's experimentally detrmined mean free path came out to be 3.7V/S. It is evident that the mean free path will depart from this statistical value if the frequency of the source is low, or the room is large, or the room has a very special geometrical shape. For instance in the case of a spherical or cylindrical chamber the mean free path $p=6V/S$ and $(3\sqrt{2}\ V/S)$ respectively. From the nature of the problem it is evident that if the statistical behaviour is realised, then the intensity will practically be constant everywhere in the room and it will be independent of the position of the source. Under these conditions the growth of sound will be given by

$$E = \frac{4P}{\Sigma\alpha S}\left\{1 - e^{\,tCS/4V\ \log\,(1-\bar{a})}\right\}$$

$$\bar{a} = \Sigma\ \alpha\ S/\Sigma S$$

where E represents the energy density at any time t at any point of the room and P the power output of the source, $\bar{a}$ the average value of the absorption coefficient. After prolonging the source for a long time the steady value of the energy density E_s comes out to be

$$E_s = 4P\ c\Sigma\alpha S$$

If you compare this result with the reverberation formula we notice that average detensity decreases as the time of reverberation decreases. Consequently the time of reverberations cannot be indefinitely decreased without impairing audibility. When the source is stopped the fall of energy density will occur in jumps at every instant p/c as given by

$$E = \frac{4P}{c\Sigma\alpha S}\, e^{\frac{CSt}{4V}\ \log\,(1-\bar{a})} \qquad ; \quad S = \Sigma s$$

Corresponding to Eyring's[6] formula for decay the time of reverberation is given by $t=.05V/S\ \log\,(1-\bar{a})$. Modifications to Eyring's formula was suggested by Millington and Sette which we shall discuss later on. These formulæ were used in general by the engineers for acoustic correction and determination of absorption coefficients.

According to Sabine's formula the logarithm of energy density should fall uniformly with time and the intensity has the same value everywhere. This is the result of the statistical theory of sound pulses, that is we have in the room an ergodic conditions with regard to the energy density.

The following oscillograms show the decay of sound in rectangular room of $8\frac{1}{4}' \times 8' \times 6\frac{1}{4}'$ for different driving frequencies namely 220, 335 and 345 cycles/sec respectively. The resonance frequencies of a rectangular room with hard walls are given by

$$\nu = \frac{C}{2}\left[\left(\frac{\eta_x}{L_x}\right)^2 + \left(\frac{\eta_y}{L_y}\right)^2 + \left(\frac{\eta_z}{L_z}\right)^2\right]^{\frac{1}{2}}$$

and the table showing some of the resonance frequencies of the above experimental room has been given below.

The first oscillogram at driving frequency 220 cycles per second shows 6 beats per sec. This is what we expect from the resonance frequencies of the room namely 215 and 221 which are excited when the source stops. Other normal frequencies are far removed from the driving frequency, consequently they are very feeble. At the driving frequency 345 cycles per second the normal frequencies 346 and 343 cycles/sec are excited and we have three beats per second. At driving frequency 335 cycles/sec the component having frequency 333 is strongly excited while the other frequencies are far removed and consequently we do not get any beat phenomenon.

TABLE 1

n_x (l)	$n_y(b)$	$n_z(h)$	ν
3	1	0	215
1	3	0	221
4	3	3	343
3	4	0	346
4	1	2	333

These experiments were repeated after covering a pair of walls by thick and coarse cloth and it is observed that the beat phenomena disappeared entirely, while the rate of decay increased considerably as shown by the fourth oscillogram at the driving frequency of 345 cycles/sec.

The index numbers which gave rise to the normal frequencies 343 and 346 are (4,3,0) and (3, 4, 0). The result of putting the cloth upon the walls was to damp the waves corresponding to the index numbers (3,4) and (4,3) and consequently the beat phenomenon was suppressed ; when the cloth was put up on the floor and ceiling corresponding to the index (0), no change was thereby made, and the beat phenomena persisted because the normal frequencies 343, 346 were present with full volume.

It will also be noticed from the decay curves that the solpe is very steep in the beginning, while at the later stages the slope decreases. The reason for this is that waves falling perpendicularly upon the walls are more absorbed than the waves that graze the surface of the walls. At the initial stages the former set of waves are strongly damped, and at the later stages only those waves are present for which the damping is small ;consequently the slope at the later stage is smaller than at the begining.

From these discussions it follows therefore that it is not desirable to put all absorbing materials on one wall ; best effect will be obtained by distributing the same over all the walls. These are the important results from the discussions of the waves phenomena, and "caution and understanding" both are necessary in order to apply Sabine's formula for acoustics correction.

The following curves show the resonance frequencies of the room with and without cloth. The prominent peaks without cloth absorbent agrees well with the calculated values. It will be noticed that the resonance peaks near 343 are very strong. Quantitative results have been obtained by Prof. N. B. Bhatt[7], and his work represents the starting point in the era of the wave theory, and the author is indebted to him for his valuable suggestions.

The resonance peaks with absorbent cloth are greatly altered both with regard to frequency and magnitude. A complete discussion of which will be presently undertaken with the help of a solution of the differential equation for the velocity potential in the rectangular chamber.

$$\nabla^2\psi - \frac{1}{C^2}\frac{\delta^2\psi}{\delta t^2} = -q\,(x,\,y,\,z;\,t) \tag{1}$$

whereψ is the velocity potential and $q(x,y,z;t)$ the volume of air introduced by an elementary source at any point (x,y,z) at the time per sec.

Let us consider a rectangular chamber with length, breadth and height along x,y and z axes, and assume that the walls perpendicular to x-axis have specific impedances.

$$Z_{x1}/c\rho = \xi_{x1} \quad , \quad Z_{x2}/c\rho = \xi_{x2}$$

Similar boundary conditions hold for other pairs of walls. We assume a steady state solution $\psi = e^{J\omega t}\,\psi_x\psi_y\psi_z$ where $\omega/2\pi$ represents the frequency of the source ψ_x,ψ_y,ψ_z are given by

$$\begin{aligned}\psi_x &= \cos h\left(J\,\frac{\chi_x\pi X}{l_x} - \phi_x \right)\\ \psi_y &= \cos h\left(J\,\frac{\chi_y\pi Y}{l_y} - \phi_y \right)\\ \psi_z &= \cos h\left(J\,\frac{\chi_z\pi Z}{l_z} - \phi_z \right)\end{aligned} \tag{2}$$

and

$$\xi_{x1} = \frac{l_x\omega}{\chi_x\pi c}\cot h\left(-\phi_x \right) \text{ at } x = o$$

$$\xi_{x2} = \frac{l_x\omega}{\chi_x\pi c}\cot h\left(J\chi_x\pi - \phi_x \right) \text{ at } x = l$$

Writing $\eta_x = \frac{\omega l_x}{\pi c} = \frac{2l_x}{\lambda}$ where λ is the wave ie the wave length of sound

and $\beta_{x1} = \frac{1}{\xi_{x1}}$ we get

$$\text{Cot}\,h^{-1}\frac{\chi_x}{\beta_1\eta_x} + \text{Cot}\,h^{-1}\frac{\chi_x}{\beta_2\eta_x} + J\pi\chi_x = 0 \tag{3}$$

where β_1 & β_2 are wall constants. Similar equations are obtained for other pairs of walls perpendicular to y and z axes.

The smallest roots[8] ofχ_x

$$\chi_0 = \left(\frac{J\eta}{\pi}\right)^{\frac{1}{2}}\left(\beta_1+\beta_2\right)^{\frac{1}{2}}\left\{1 - \frac{J\pi}{6}\,\eta\,\frac{\beta_1^3+\beta_2^3}{(\beta_1+\beta_2)^2} + \ldots\ldots\right\}$$

and

$$\chi_n = n + \frac{J\eta}{\pi n}(\beta_1 + \beta_2), \quad n > 0 \tag{4}$$

Similarly equations for other pairs of walls.

In the case of free vibrations we assume $q=0$ and $\psi = \psi_N e^{J(\omega_N + Jk_N)t}$ where $\psi_N = \psi_x \psi_y \psi_z$

Substituting this value of ψ in (1) we find

$$\nabla^2 \psi_N + \frac{(\omega_N + Jk_N)^2}{C^2} \psi_N = 0$$

i.e.

$$\pi^2 C^2 \left\{ \left(\frac{\chi_x}{l_x}\right)^2 + \left(\frac{\chi_y}{l_y}\right)^2 + \left(\frac{\chi_z}{l_z}\right)^2 \right\} = (\omega_N + Jk_N)^2$$

Writing $\chi_x = \mu_x + jk_x, \ \chi_y = \mu_y + jk_y, \ \chi_z = \mu_z + jk_z$

We get

$$\omega_N = \pi C \left\{ \frac{\mu_x^2 - k_x^2}{l_x^2} + \frac{\mu_y^2 - k_y}{l_y^2} + \frac{\mu_z^2 - k_z^2}{l_z^2} \right\}^{\frac{1}{2}}$$

$$K_N = \frac{C}{4} \left\{ \frac{4\pi\mu_x k_x}{\eta_x l_x} + \frac{4\pi\mu_y k_y}{\eta_y l_y} + \frac{4\pi\mu_z k_z}{\eta_z l_z} \right\}$$

where $\omega_N/2\pi$ and k_N denote the characteristic Natural frequency and the wave damping coefficient. Let us interpret these results.

Writing

$$\frac{1}{\xi} = \nu + J\sigma$$

we find

$$\left.\begin{array}{rl} \mu_x^3 - k_x^2 = & -\left(\frac{\eta_x}{\pi}\right)\left(\sigma_1 + \sigma_2\right) \\ & n^2 - \left(\frac{2\eta_x}{\pi}\right)\left(\sigma_1 + \sigma_2\right), \ n > 0 \\ \frac{4\pi\mu_x k_x}{\eta_1} = & 2(\nu_1 + \nu_2), \quad n = 0 \\ = & 4(\nu_1 + \nu_2), \quad n > 0 \end{array}\right\} \tag{5}$$

$$\text{and } K_N = \frac{C}{8V}\left\{ 8(\nu_{x1} + \nu_{x2}) S_x \varepsilon_x + 8(\nu_{y1} + \nu_{y2}) S_y \varepsilon_y + 8 (\nu_{z1} + \nu_{z2}) S_z \varepsilon_z \right\}$$

$$\text{where} \quad \left.\begin{array}{ll} \epsilon = 1 & n > 0 \\ \epsilon = \frac{1}{2} & n = 0 \end{array}\right\} \tag{6}$$

S_x, S_y, S_z represent wall areas perpendicular to x, y and z axes respectively.

Let $\alpha_N = 8\,[(\nu_{x1} - \nu_{x2})\,S_x\varepsilon_x + (\nu_{y1} + \nu_{y2})\,S_y\epsilon_y + (\nu_{z1} + \nu_{z2})\,S_z\epsilon_z]$ (7)

then $K_N = C\alpha_N/8V$ (8)

Writing $E_N = E_{0N}\,e\,{-2k_N t}$, we find $t_N = \cdot 049/a_N$ (9)

t_N denotes the reverberation time for the Nth component, and V the volume of the room. These represent the fundamental formulae which are used for room acoustics.

Two facts emerge out of this expression, firstly the time of reverberation i.e. the rate of decay will be different for different modes acording as the values of ε_x, ε_y ε_z are unity or half according to n_z, n_y, n_z etc. are all greater than unity or zero. If n_x, n_z and n_z are all greater than unity then a_N will be given by (7) and it will be the same for other components for which this condition is satisfied. If $n_x = 0.\ n_y\ n_z > |$ the wave system is designated as tangential type, the value of a_N is then accordingly different from (7). Similarly for axial waves $n_y = n_z = 0$, $n_x > |$ the value of α_N will alter profoundly. In the case one wall soft and the other fairly hard, the absorption of both walls is not additive as indicated by formula (7) a_N gives the normal coefficient of absorption, and it does not represent Sabine coefficient

FORCED VIBRATIONS :—Let us assume that the source function can be expressed

$$q(x, y, z\,;\,t) = \sum \psi_N(\omega) A_n c^{j\omega t}$$

for almost hard walls

$$\psi = -\frac{c^2 Q_0}{V} \sum \frac{1}{\Lambda_N} \frac{\psi_N(x_0, y_0, z_0)\,\psi_N(x, y, z)\,e^{j\omega t}}{\{\varpi^2 - (\omega_N + jk_N)^2\}} \quad . \qquad (10)$$

where

$$Q_0 = Q\Delta V\ ;\ \Lambda_N = \Lambda_x \Lambda_y \Lambda_z\ ;\quad \left.\begin{matrix} \Lambda_x = 1 & n_x = 0 \\ \Lambda = \frac{1}{2} & n > 1 \end{matrix}\right\}$$

Since

$$p = \rho \frac{d\psi}{dt} = \rho j \varpi \psi$$

We obtain

$$p = \frac{-c^2 \rho j Q_0 e^{j\omega t}}{V} G_{NN}(x_0, y_0, z_0\,;\,x, y, z)$$

where 'G' is known as Green's source function. When the source is at one corner $\psi_N(x_0, y_0, z_0) = 1$and then

$$p^2 = \frac{c^4 \rho^2 Q_0^2}{2V^2} \sum \frac{1}{\Lambda_N^2} \frac{\omega^2 \psi_N^2}{\{(\omega^2 - \omega_N^2 + k_N^2)^2 + 4k_N^2 \omega_N^2\}} \qquad (11)$$

If we dealing with an isolated single mode of vibration, then the summation sign may be removed. In that case for a given position of source and observer the maximum value of p^2 is $c^4 \rho^2 q^2/8V^2 \Lambda_N^2 k_N$ and the ratio of $(p\,\omega^2/p^2_{max})$ is given by

$$\frac{|p\omega|^2}{p^2_{max}} = \frac{4\omega^2 k_N^2}{\{(\omega^2 - \omega_N^2 + k_N^2)^2 + 4\omega_N^2 k_N^2\}} \qquad (12)$$

If we have two impressed frequencies ϖ' and ϖ'' above and below the peak frequency such that the above ratio *is half in each case*, then we get

$$\varpi'\omega''=\varpi_N^2+k_N^2$$

$$\varpi''-\varpi'=2k_N \qquad (13)$$

subject to the condition that the square of the band width be negligible in comparison to the square of the resonant frequency.

Equation 13 has been used by C. M. Harris[9] to determine the decay constant by shifting the frequency of a Beat Frequency Oscillator from the resonance point to a point where pressure was reduced by a factor $\sqrt{2}$. $\varpi'4\omega''$ were measured by a specially calibrated incremental pitch condenser reading upto .04 cycles/sec. It is important to have stable oscillator in making these measurements. The measurements were carried for different modes i.e. for different values of n_x, n_y, n_z. A typical pressure curve for an isolated mode is shown in Fig. 2*b* which shows the distribution of pressure along x axis for a mode $(n_x,n_y,n_z)=(0.0.1)$, $l_x=7.84'$, $\frac{\varpi}{2\pi}\sim 122$; $x=0$ wall is bare and hard $\phi_x=0$. The other wall is covered with celotex $\nu+j\sigma=.02+j\times .06$.

$$\pi\mu_x \eqsim \cdot 05$$

$$\pi k_x \eqsim \cdot 162$$

It will be noticed that the pressure at the other wall is greater than that at the reflecting hard wall. This is due to the negative reactance of the material used.

When we take the space average we find

$$p^2_{av}=\frac{c^4\rho^2Q_0^2}{2V^2}\sum\frac{\omega^2}{\Lambda_N^2}\,\frac{1}{\{(\omega^2-\omega_N^2+k_N^2)^2+4\omega_N^2k_N^2\}}$$

If we assume that $n_x, n_y, n_z>1$ i.e. there are oblique waves, the number of components having frequencies between ϖ_N and $\varpi_N+d\varpi_N$ is

$$\frac{V}{2\pi^2c^3}\varpi_N^2d\varpi_N$$

We multiply the above expression by this quantity and integrate between $-\infty$ to $+\infty$, the result is

$$p^2_{av}=\frac{c\rho^2Q^2\varpi^2}{16\pi V}\frac{1}{\Lambda_N}\frac{1}{k_N}, \quad \text{since} \quad \frac{1}{\Lambda_N}=8$$

$$\text{or} \quad p^2_{av}=\frac{4\rho^2Q_0^2\varpi^2}{\pi a_N}$$

where k_N is given by(8)

This is to be compared with Sabine's statistical result

$$p^2_{r\cdot m\cdot s\cdot}=\frac{4\rho^2\varpi^2Q_0^2}{\pi a_s},\ a_s=\sum\alpha_sS$$

Measured by the band width method

The difference lies in the coefficients α_N and a_s ; in the former case α_N represents the absorption coefficient, while α_s is the statistical value of the same for diffused sound.

EFFECT OF NON UNIFOEM DISTRIBUTION OF ABSORBING MATERIAL:—

It has been generally recognised that better room acoustics can be obtained by distributing absorbing material in patches over walls of a room than by uniformly covering the walls. Also measurements show that the decay curve and pressure distribution due to a sound source are dependent *not only on the quantity and admittance of the absorbing material, but on its position and distribution.* The theory of acoustics of rooms with walls non-uniformly covered by absorbing material can be worked 1) by the method of successive approximations, 2) by Fourier expansions and 3) by the application of Dirac's δ function.

Let us consider the case of a rectangular room where the walls are non-uniformly covered by absorbing material. We assume ψ_N the normal potential functions for hard walls, so that $\nabla\psi_N + \frac{k_N{}^2}{C^2}\psi_N=0$ when the admittance of the wall is zero. In the case when the walls are non-uniformly covered by patches we asume ψ' which satisfies

$$\Delta^2\psi'+\frac{k'^2{}_N}{c^2}\psi'=0$$

where k'_N is complex. Let $k'^2{}_N= k^2{}_N + \varepsilon$, so that
$$k'_N=k_N+\epsilon/2k_N$$

Now
$$\psi_N\nabla^2\psi_N'-\psi_N'\nabla^2\psi_N+\frac{\epsilon}{c^2}\psi_N\psi'_N=0$$

or by Green's theorem

$$\int\int\psi_N\psi'_N\left(\frac{1}{\psi_N}\frac{d\psi'_N}{dN}-\frac{1}{\psi_N}\frac{d\psi_N}{dN}\right)ds+\frac{\epsilon}{c^2}\int\int\psi_N\psi'_N dv=0$$

At
$$\beta=0,\ u/p=\beta k'_N/c\ ;\ \beta=j\sigma+v$$

If
$$\psi_N\sim\psi_N',\text{ then }\epsilon=-ck_N{}'\frac{\int\int\beta\psi_N{}^2ds}{\int\int\int\psi_N{}^2dv}$$

$$\omega_N'=\left\{\omega_N-\frac{c}{2}\frac{1}{V\epsilon_N}\int\int\sigma\psi_N{}^2ds\right\}$$

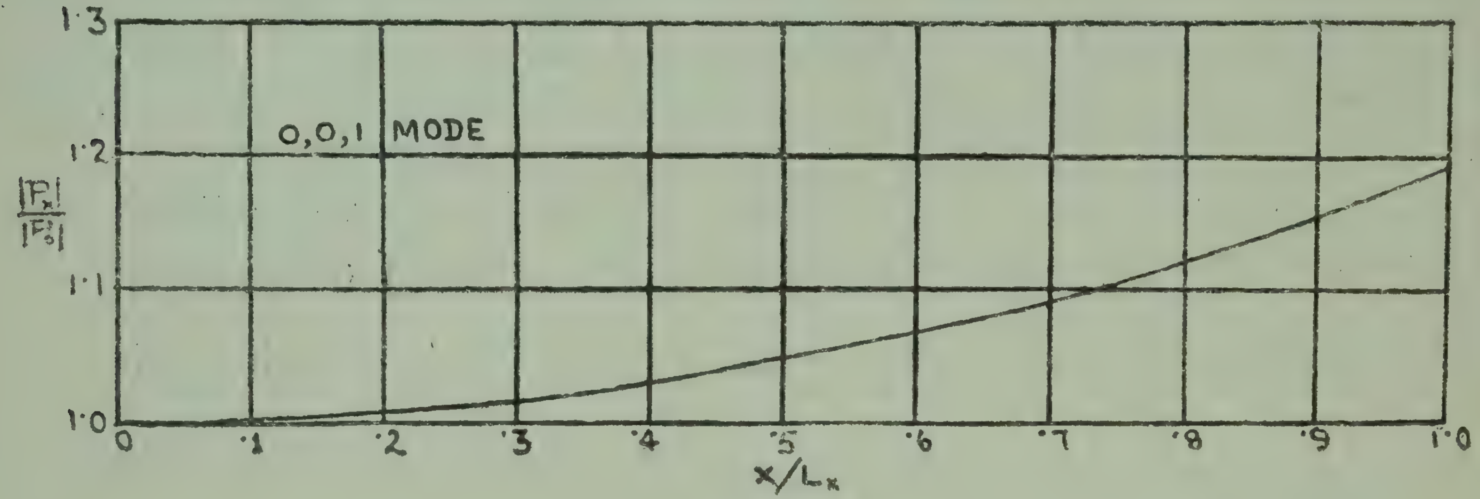
$$k_N\ (\text{damping}) = \frac{C}{2V_0\epsilon_N}\int\int v\psi_N{}^2\,dS \qquad (10)$$

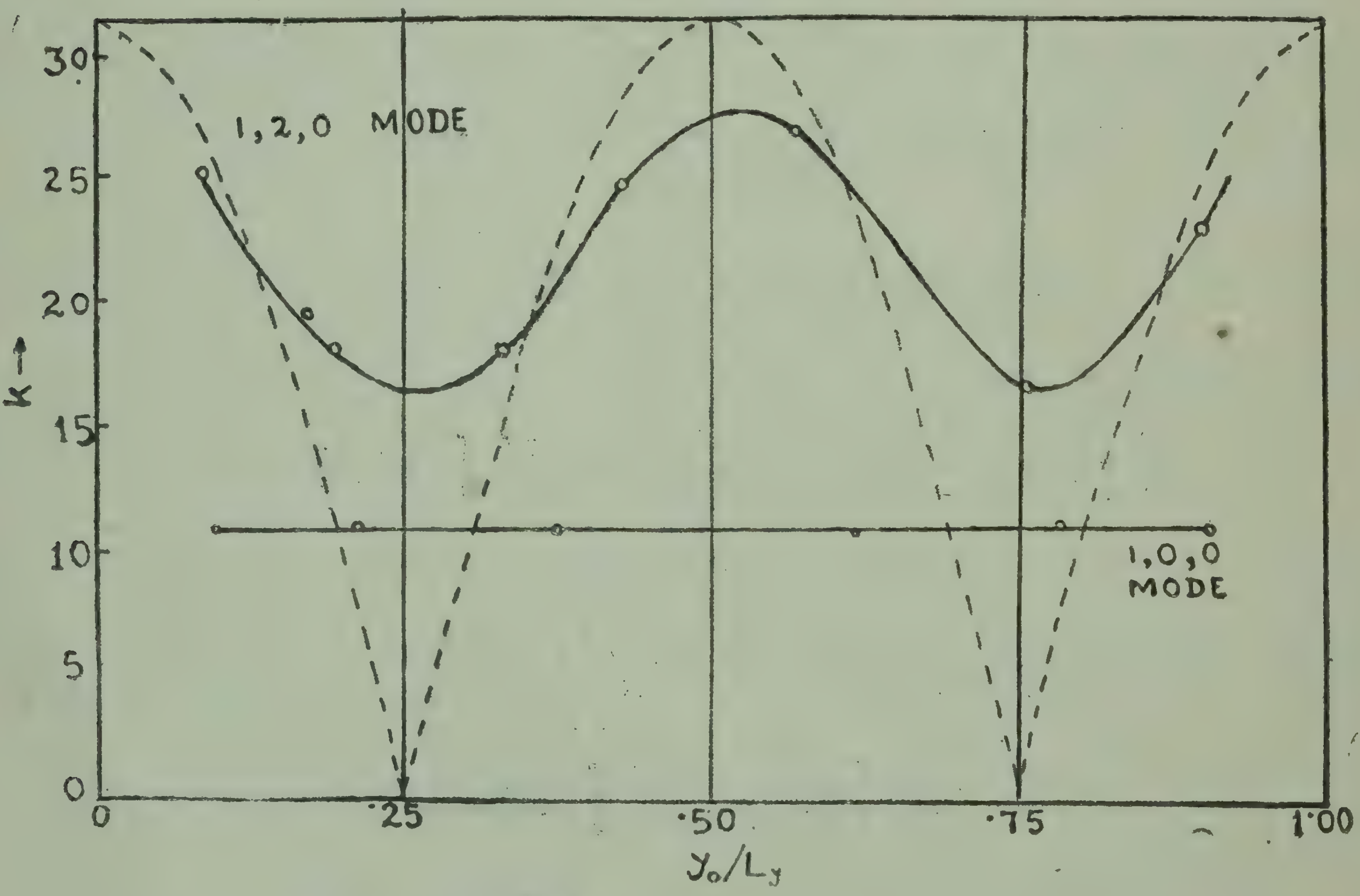
where E_N represent the mean square value of ψ_N over the entire room.

The mean squares ψ_Ns will therefore have a decay factor $\text{Exp}\left[-\frac{C\alpha_n t}{4V}\right]$

where $\frac{\alpha_N}{S} = \frac{8}{2S\epsilon_N}\int\int v\psi_N{}^2\,dS$

where S represents the total area of the walls. Several interesting conclusions can be drawn from this first order result. It will be noticed that a piece of absorbing material produces most effective absorption where most of the wave functions have their maxima. In a rectangular chamber, the corners therefore are the best portions for placing absorbing materials. Next best portions are the edges of the walls. In the second place we observe that if the material is to be spread over a number of walls, it is better to place patches of the material in a rather irregular fashion over the walls rather than spreading them uniformly over a wall, since a regular pattern is sure to fall on the minima of some wave functions.





With a single isolated mode of vibration in a small experimental chamber l_x, l_y, l_z, 10″, 8″, 9″ with 5/8″ thick walls, Harris 11) of M.I.T. investigated the absorption due to a patch of material by varying its position on the floor at a fixed distance 'Z' and progressively increasing its distance along Y axis (X-axis being vertical). *Fig.* 2 shows the relative absorption *Fig* 2a for a mode $(n_x, n_y, n_z) = (1, 2, 0)$ frequency 1820. The dotted curve shows the pressure variation in the absence of the patch. It shows two pressure modes as it should be. It will be observed that the absorption is maximum at the pressure maximum. The other curve shows the same for a mode (1,0,0) *Fig* 2b frequency 675; no pressure variation along Y-axis and no change in the relative absorption.

If the absorbing material on a wall is uniformly spread over regions large compared to the wave length, then $\iint \gamma \psi_N^2 ds \equiv S$ times the constant value of β multiplied by the mean square value of ψ_N on the wall in question,

Hence $\alpha_N = 8(\nu) e_N$

$$e_N = \tfrac{1}{2} \frac{\text{average value of } \psi_N^2 \text{ over the surface}}{\text{average value of } \psi_N^2 \text{ over the entire volume}}$$

Coming back to the case of uniformly covered walls equation gives at once

$$K_N = \frac{e}{8V} [8 (\nu_{x_1} + \nu_{x_2}) \epsilon_x S_x + 8 (\nu_{y_1} + \nu_{y_2}) S_y \varepsilon_y + 8 (\nu_{z_1} + \nu_{z_2}) \epsilon_z S_z]$$

Let us consider a specific case of a room where all the walls are hard except the walls $x = 0$ $x = l$, which are uniformly covered by patches. In this case we express

$$\beta_{x1} = \sum \beta \mu \nu \cos \frac{\mu \pi g}{l_y} \cos \frac{\nu \pi z}{l_z}$$

where

$$\beta_{\mu\nu} = \frac{4}{l_y l_z} \int \int \beta_{x1} (yz) \cos \frac{\mu \pi y}{l_y} \cos \frac{\nu \pi z}{l_z} dydz$$

the factor 4 being replaced by 2 or 1 when one or both μ & ν are zero. With the help of equation (10) we get

$$K_N = \frac{C}{2} \left[e_{nx} \frac{(\beta_{x1} + \beta_{x_2})}{l_x} \right], \ \beta_{x1} = \frac{4}{l_y l_z} \int \int {}_N\psi^2 \beta_{x1} d_y d_z$$

or $\beta_{x1} = \beta_x ; O, O + \tfrac{1}{2} \{\beta_x ; 2\eta_y, O + \beta_x ; O, 2\eta_z\} + \tfrac{1}{4} \beta_{x1} ; 2\eta_y, 2\eta_z$

and similarly for β_{x_2}. These results can be extended to other non-homogeneously covered walls in the same manner.

These methods have however been replaced by more powerful and elegant ones due to the application of δ function. We shall quote some important results.

ERGODIC WAVE MOTION AND INDEX OF RANDOMNESS:—

From these investigations Morse and Bolt have deduced that the wave motion becomes ergodic when patches of material are irregularly distributed over the walls, or the room is irregularly shaped. In the former case the criterion is given by "The index of Randomness" I.R. $_{12}$) for a rectangular chamber

$$\text{I. R} = \frac{\tfrac{1}{2} |\beta| S_\alpha}{\lambda^2 + (4S_\alpha / m)}$$

where $S_\alpha = m\,(ab)$, ab area of the patch of material and $\beta = c\,\rho / z$, λ the wave-length of the sound from the source; m number of patches. When I.R. is smaller than unity, the wave motion is not ergodic (an ergodic wave motion is completely diffuse) in which all the statistical formulas apply —the normal modes having wave-lengths of the order of λ, do not decay at the same rate and the decay curve is not a straight line. When I.R. is considerably larger than unity, the wave motion becomes ergodic—diffuse, the decay rates of the contiguous mode approach an average value; the formulas of geometrical acoustic are then valid. It will be noticed that I.R. will be considerably smaller than unity for very low frequencies. The effect of perturbation of the shape of the wall by bumps or bulges was also considered by Morse & Bolt. We hope to listen to Dr. Auluck's lecture on this subject.

ABSORPTION COEFFICIENT AND ACOUSTIC IMPEDANCE

The discussion on wave acoustics of rooms has led to believe that the room method of determining absorption coefficient will not give correct or consistent results unless I.R. >1* and this involves previous knowledge of the acoustic properties of the room. Repeatable results for the absorption coefficient at normal incidence are obtained by the standing wave method. One of the earliest methods depending upon this principle is due to Paris who used hot wire microphone as detector. A set of clay pipes, diameter about 1′, was jointed together at one end of which a loud-speaker represented the source of sound to produce standing waves, and at the other end in the groove of the pipe a perfect reflector consisting of a thick (1/4″) brass plate was fitted, this could be used as a backing plate to any material cut to the shape of the groove. A sliding wire carrying the microphone at one end detects the sound intensity at different places. The space between the backing plate and the groove has to be made air tight or sound tight so that no sound can leak through it.[13]

The detecting instrument consisted of a cylindrical resonator which could be adjusted to the frequency of the sound, and a hot wire grid—fine platinum wire, diameter .004 mm., carrying 26 milli-amperes, resistance 340 ohms. At the maxima of *particle velocity* the resistance fell by 28 ohms depending upon the heating current and sound intensity. The change of resistance is measured by a battery bridge. Stability of the balance is obtained by inserting a dummy hot wire resonator in the side branch.

It is needless to mention that great caution is required in using the hot wire instrument with a battery bridge which can burn away the fine wire at any slight excess of current.

This method is selective and is very sensitive. The absorption coefficient α is given by

$$\alpha = \frac{4}{(2 + \frac{a}{b} + \frac{b}{a})}$$

where a & b are the amplitude of sound at maxima and minima respectively. The resistance changes are then converted in terms of distances from the minima by replacing the material with the perfect reflector. The ratio $\frac{a}{b} \sim \frac{\sin k_{x1}}{\sin k_{x2}}$, where $k = 2\pi/\lambda$ and $_{x1}$ & $_{x2}$ are distances from the minima when the perfect reflector is introduced.

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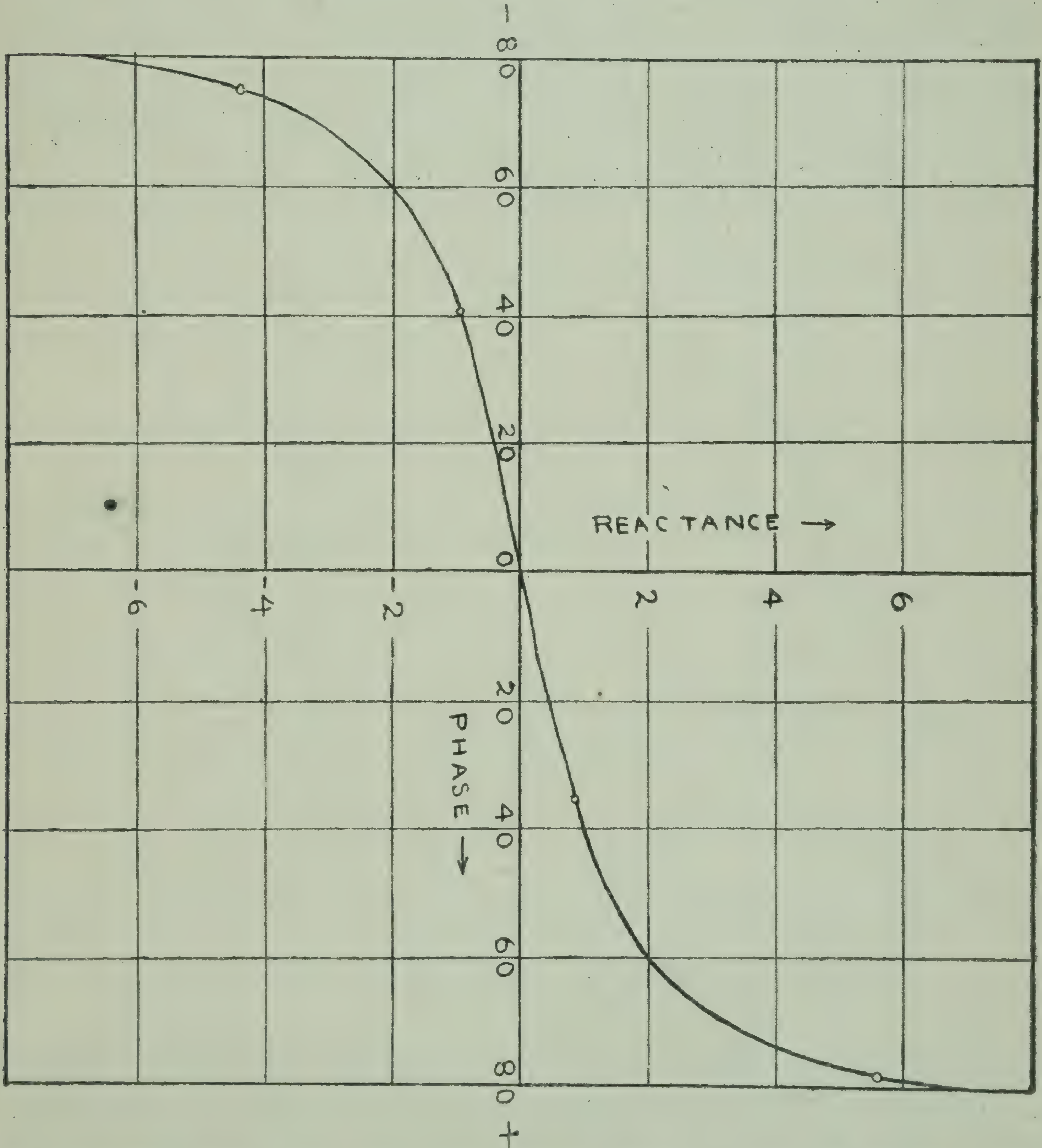
* Sabine noticed variation on the value of the absorption coefficient determined by the room method, for instance the absorption coefficient altered from .43 to 1.26 at 1024 when the sample was shifted from one position to another.

A large pipe of the diamensions used in the experiments is liable to produce radial vibrations which would impair the results.

It will be observed that this method could be used in a more simplified form by replacing the hot wire microphone by a telephone receiver and amplifying the input sound and using a copper oxide rectifier and a galvanometer in the output of the amplifier; the 'noise' from the amplifier is most troublesome in this case. With some caution this simple method gives quick results sufficiently accurate for industrial purposes.

Impedance Circle Method

Dr. Miss Chandra Kanta[14] developed impedance circle method to sufficient accuracy so that load impedance due to acoustical systems could be measured. The method consists in coupling a moving coil speaker of low impedance to an air column in a pipe and determining the impedance of the speaker with and without the air column of various lengths. The resistance and the reactance components are separately determined by means of Campbell's inductometer.



$$Z_{ET} - Z_{EW} = \frac{k^2}{R_p + j(X_p - aZ_o \cot kl)} = R_E + X_E j$$

$ja\ Z_0$ Cot kl represent the load impedance to the speaker

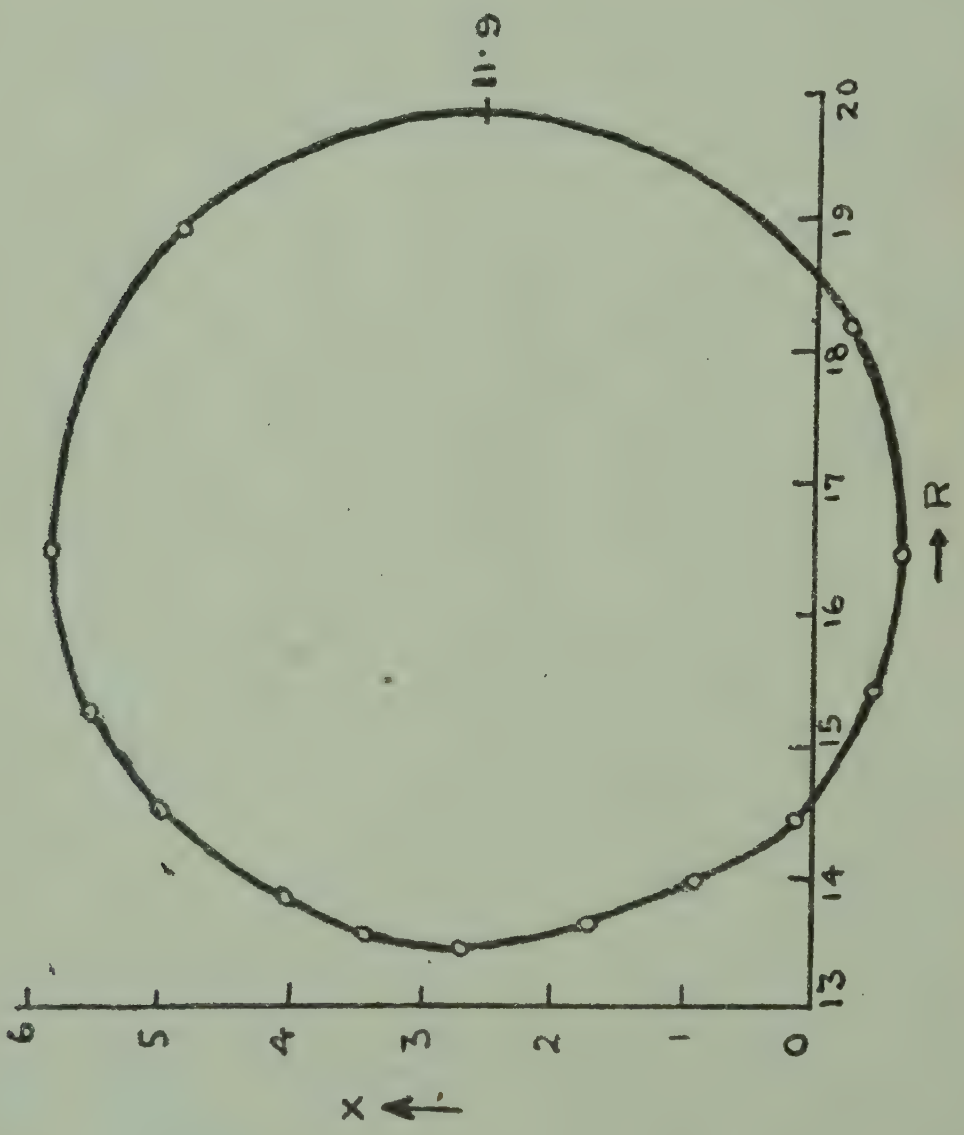
We write this in the form

$$R_E + jX_E = \frac{k^2}{R_p + jX'_p}$$

the quantity—J cotkl represents the air column impedance with a perfect reflector at the end which is added to the mechanical impedance of the system. We find

$$\left(R_E - \frac{k^2}{2R_p}\right)^2 + X_E{}^2 = \left(\frac{k^2}{2R_p}\right)^2$$

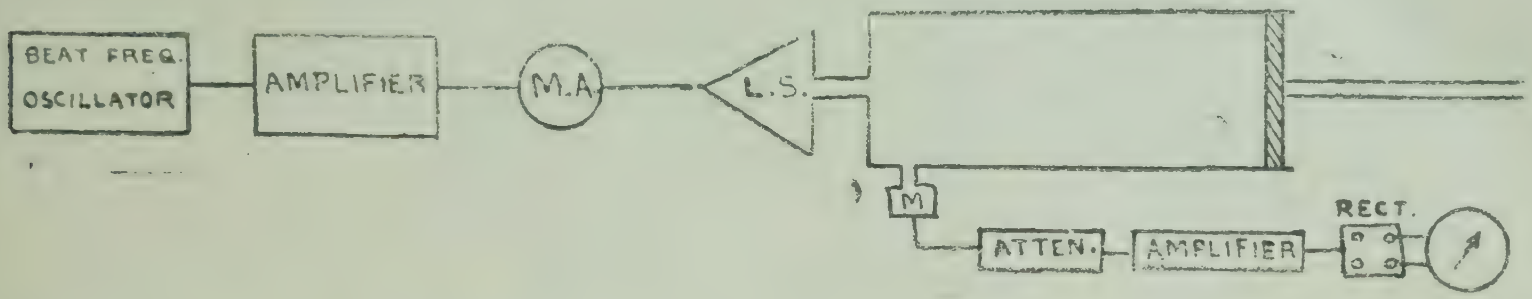
Hence when R_E and X_E are plotted on real and imaginary axes we get impedance circle as shown in Fig. Dr. Miss chandra Kanta used the impedance circle to determine the load impedance and thence the impedance of the imperfect reflector— viz. felt, celotex etc. Dr Chandra Kanta used a pipe of aboug 4″ diameter, a pipe of larger diameter will certainly yield results of sufficient accuracy comparable with other methods.



The impedance of Helmholtz resonators fixed to the perfect reflector was also determined by this method ; the phase angles for five resonators are plotted and shown in Fig. 4 These are well known curves. At resonance the phase angle is zero ; while on both sides of resonance the phase angle does not extend beyond 90°. These curves lend support to the accuracy of the experimental method.

Half Peak Width Method of Determining Absorption Coefficient :—

This method[15] is now universally used for accurate determination of acoustical impedances of materials. We have adopted this method for determinations as primary standards.



The arrangement is shown above in the block diagram. Fig. 5. The Ls feeds the sound chamber thorugh a high impedance channel, so the reaction on the source is negligible. The piston is adjusted for resonance and the attenuator is set to a high value, and the deflection of the galvanometer is noted. Then the attenuator reading is decreased in steps of a *db* and the pistons moved once outside and then inside the resonance lengths so that the same deflection is again obtained. In this manner readings are taken for several steps of 1 *db*. It is very necessary that the frequency should remain constant when these readings are taken. For this purpose tested tuning forks of high frequency magnetostriction oscillators are used to test the frequency. Similarly the temperature inside the sound chamber must be noted and necessary corrections made. Assuming that radial vibrations are not present, the damping coefficient is given by

$$k = \pi f(l'' - l')/l(w-1)^{\frac{1}{2}}$$

$\left(\text{where } l', l'', l \text{ are the lengths of air column, } w = \frac{|p_m{}^2|}{|p'^2|} = \frac{|p_m{}^2|}{|p''^2|}\right)$ where p', p'' represent the pressure for the corresponding lengths l', l'' and f the frequency of the sound waves.

Since the measurements have been taken in dbs, x dbs. change from resonance will correspond to $w = \frac{x}{10}$ $l.'l''$ are read on the scale of piston corresponding to x db change. Thus all the quantities are known. Hence k is determined. If k be the total damping coeffiecient, kna the same when the perfect reflector is used

$$km = k - kna$$

where km represents the same due to absorption of the material set upon the backing plate. The impedance z is calculated from

$$\frac{Z}{\rho c} = \cot l\left[\left(k - kna\right)\frac{l}{c} + \frac{j\omega}{c}\left\{l_0 - \left(1 - \frac{k^2}{2\omega^2}\right)\left(\frac{t_0}{t_x}\right)^{\frac{1}{2}} l\right\}\right].$$

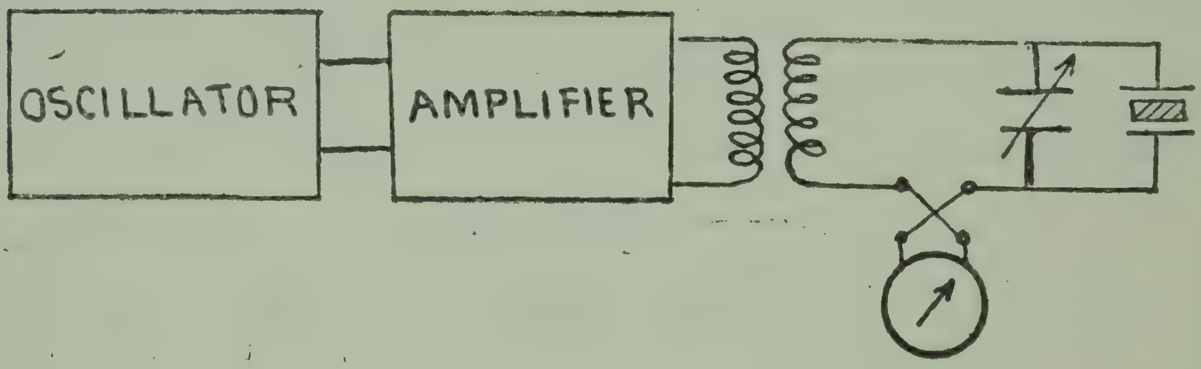
where t_0 and t_x are the absolute temperatures of air inside the tube without and with material backed upon the plate and temperature correction into account. The following curve shows the value of $R/c\rho$ and $X/c\rho$ in the case of three materials viz. celtoex, felt and celotex. Results are within 1 % One important result deserves mention, the materials with negative reactance draw the pressure nodes near them and produce more effective absorption.

PHYSICAL PROPERTIES OF MATERIALS AND ABSORPTION :-

Attempts have been made in recent years to correlate the absorptive power with the physical properties of materials, viz. porosity, flow resistance etc. It would certainly be of great help in the search and preparation of suitable materials for large scale use in theatres and halls. These experiments predict the behaviour of indegenous material such as bagasse or Indian grass. We may mention here that some samples prepared by the Forest Reaserch Institute, Dehradun have been found to possess high sound absorbing qualities and suitable for large scale use.

ULTRASONIC ABSORPTION

We have referred to the determination of coefficient of liquids by Dr. Parthasarathy by optical means. The reaction of the standing wave upon the vibrating quartz crystal gives another means[16] by which the absorption coefficient can be determined readily. As the perfect reflector is moved and the resonance lengths are increased the reaction decreases exponentially. The equivalent resistance R and the capacity K of the vibrating crystal change to $R+\Delta R$ and $K+\Delta K$, and on account of these changes the current in the resonance circuit changes and measured by the thermocouple milliammeter for various positions of the reflector x. Let $\sigma=i/I$, where I represents the maximum current when the crystal is disconnected, then we reduce the reaction by means of the standing wave and the effective changes ΔR and ΔK



$$\left[\frac{1-\sigma\min}{\sigma\min}\right]\left[\frac{\sigma\max}{1-\sigma\max}-\frac{\sigma\min}{1-\sigma\min}\right]\left(1+x\frac{\alpha}{\beta}\right)=\text{const.}$$

to α/β is determined from a series of i_m and x, α being the absorption coefficient, β=reflection coefficient.

The reaction in the case of gases is small and requires very accurate adjustment. Some measurements have been taken at 1.46 M.C. in CO_2 and air at different humidities. These values agree with the classical value.

In the case of liquidsρ v is very large ($\sim 10^5$). Hence the above formula reduces to

$$x\,\alpha=\frac{C}{S}\;\frac{\sigma_{\min}}{1-\sigma_{\min}}+\text{const.}$$

Putting $y_1=\sigma_{\min}/(1-\sigma_{\min})$ and noting the slope from the plot of y_1 against x, α is determined. The following table gives the absorption in various liquids for requencies 1.46 MC and 4 M C S.

TABLE

Liquid	Frequency	Temperature	$\alpha(\mathrm{cm}^{-1})$	$\frac{\alpha}{N^2} \times 10^{17}$ $\mathrm{sec}^2\ \mathrm{cm}^-$	Velocity Metres/Sec.
Benzene	1.46 Mc	23°C	.02	940	1320
Acetic Acid	1.46 Mc	23°C	.16	7619	1253
	4 Mcs	23.2°C	.344	2150	1231
Transformer oil	1.46 Mc	23°C	.002	104	1284
Carbon-tetra-chloride	1.46 Mc	23.6°C	.011	507	930
	4 Mc	24°C	.083	520	928

These results are in agreement with the results obtained by other methods. All these absorption coefficients are much higher than the classical values. Transformer oil belongs to that class of liquids of which the absorption is due to viscosity alone.

The Benzene and Carbon-tetra-chloride class are unassociated liquid. In these cases the absorption is about hundred times the classical value. In the case of Acetic Acid two different frequencies namely 1.46 Mc and 4 Mcs were investigated. The following curve is plotted with α/N as ordinate and Log N as abscissa and shows the results of other workers as well as the values determined in our laboratory, It will be observed that acetic acid has got high dispersion in the region of 2.5 Mcs and the maximum absorption takes palce at 2.5 Mcs. The existence of such a maxima was pointed out by Dr. A. K. Dutta[17] in 1941 and with the help of his formula the dispersion in velocity comes out to be 1.4%. In the case of unassociated liquids it has been pointed by Buaer that the maximum of absorption lies in the neighbourhood of one thousand mega cycles and consequently interferometer can not be used to locate them. We have, however, secured a number of crystals of various frequencies and we wish to try some liquids whose behaviour could be known from viscosity data, which we shall presently discuss in the next section.

THEORETICAL DISCUSSION

It will be known that the absorption in the case of polyatomic gases can be attributed to the excitation of vibrational levels of the molecules by the ultrasonic waves, that the absorption is due to lag between the excited molecules returning to their normal levels and time period of vibration of the ultrasonic waves which is known as relaxation phenomenon. In 1938 Kneser applied the same mechanism to explain the phenomenon of absorption in the case of liquids also, that is, it is assumed that in the case of liquids also the molecular vibrational levels are also excited. Recently Bauer has calculated thermodynamically the velocity in the same manner as by Dr. Dutta and evaluated the maximum absorption coefficient with the help of vibration frequencies. Similarly he has tabulated frequencies of maximum absorption with the help of absorption data and the internal specific heat as calculated from the contributions of vibration frequencies. This mechanism is widely believed to be the only factor that contributes to the absorption of ultrasonics energy in the liquids. Sometime back in 1945 Dr. Auluck and Dr. Kothari drew attention that the hole theory of liquids with their quantised values may contribute to the ultrasonic absorption phenomenon. Frenkel also has mentioned in his book that the quasi-crystalline structure of the liquid must take part in the phenomenon of absorption. The authors believe that the hole theory which postulates a quasi-crystalline structure of the liquid must play an important role in the phenomenon of absorption, and dispersion of ultrasonic waves. The quantised hole theory leads to the difficulty of evaluating the energies due to quasi-crystalline structure of the liquid. But the theory of viscosity of liquids based on same assumption makes it possible to evaluate the energy of the quasi-crystalline state of the liquid. The viscosity η^{18} in the case of liquids is given by

$$\eta = \mathrm{B}\,\frac{\mathrm{T}}{\mathrm{T_m}}\; e^{\mathrm{A/RT}}$$

If η and η' be the viscosities at temperature T and T′

$$\eta = \mathrm{R}\cdot\frac{\mathrm{TT'}}{\mathrm{T'-T}}\,\log\frac{\eta\mathrm{T'}}{\eta'\mathrm{T}} \quad \text{for a gram molecule where}$$

A is work function for gram molecule.

Now the internal specific heat $\mathrm{C_i}$ is given by

$$\mathrm{C_i} = \mathrm{R}\left(\frac{\mathrm{A}}{\mathrm{RT}}\right)^2 \mathrm{Exp}\,(-\mathrm{A/RT})$$

The maximum absorption per wave length is

$$2\mu_{\mathrm{m}} = \pi\,\frac{\gamma'}{\gamma}\;\frac{\gamma-1}{\mathrm{C_p}}\cdot\mathrm{C_i}$$

where γ' represents the ratio of specific heats when ultrasonic absorption takes place and γ the same without absorption. The dispersion frequency is given by

$$\mathrm{N_m} = \left(\frac{2\mu_{\mathrm{m}}}{\mathrm{C}}\right)\left[\frac{1}{(\alpha/\mathrm{N}^2)}\right]\quad \mathrm{N}\leqslant\mathrm{N_m}$$

The following table gives the values of α/N^2, μ_{m} and $\mathrm{N_m}$ etc.

The experimentally determined value of maximum dispersion frequency in the case of acetic acid is 2.5 Mcs. while the hole theory gives 4.87 Mcs. If we assume that there are vibrational levels in addition, the requisite value of $\mathrm{C_i}$ comes out to be .246 cal. $\mathrm{deg.^{-1}}$ $\mathrm{mole^{-1}}$ and 'A' is 7211 cals/mole. Subtracting from this the hole energy 3291 cals/mole we get 3290 cals/mole—the additional vibrational energy corresponding to frequency 1381 ± $5\mathrm{cm^{-1}}$ for monomer Acetic Acid.

TABLE

Substance	$\frac{\alpha}{\bar{N}^2} \times 0^{17}$ Sec^2Cm^{-1}	$C \times 10^5$ Cms/Sec	A Cals/ mole	Ci Cal $dag^{-1}mole^{-1}$	$2\mu_m$	N_m.
Carbon-di-Sulphide	10'800	1.14	1802	.8937	.2789	23
Benzene	830	1.31	3148	.2769	.0979	90
Carbon-tetra-chloride	513	.91	3330	.2297	.0652	140
Chloroform	380	.987	2291	.6446	.1806	480
Chloro-benzene	123	1.302	2771	.4295	.1540	963
Toluene	84	1.31	2207	.9181	.2278	2070
Acetone	60	1.17	2250	.6486	.2301	3278
Ethyl-bromide	56	.932	1812	.864	.2608	5067
Acetic Acid	12,000	1.2	3291	.2423	.0701	4.87

APPLICATION OF ULTRASONICS

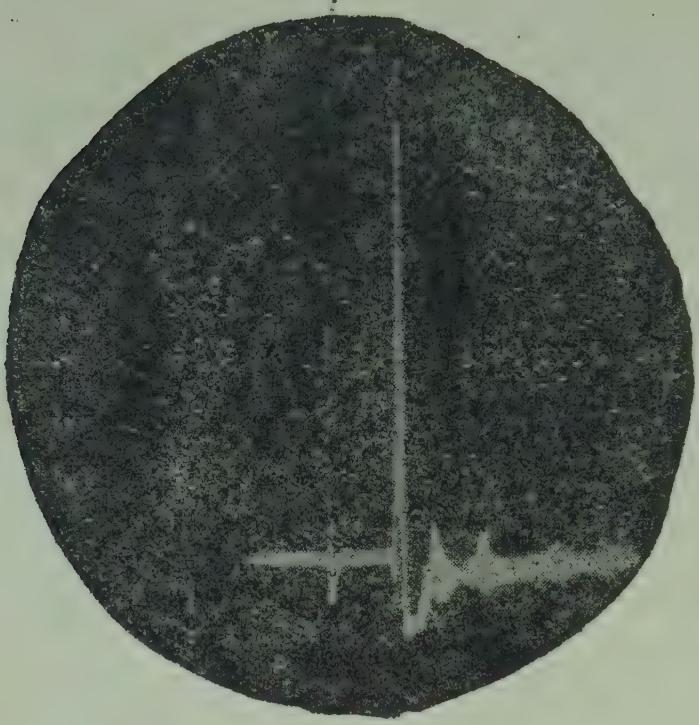
One of the most interesting application of ultrasonics is the determination of elastic constants of solids with the help of the total reflection of the longitudinal and the shear waves when a plate of the solid is rotated in a liquid. The longitudinal wave which is incident upon the surface of the plate is broken up into two waves-longitudinal and shear waves. The critical angle is different for the two waves hence by rotating the solid plate around a vertical axis, first the longitudinal transmitted wave vanishes and then the shear wave.[19]

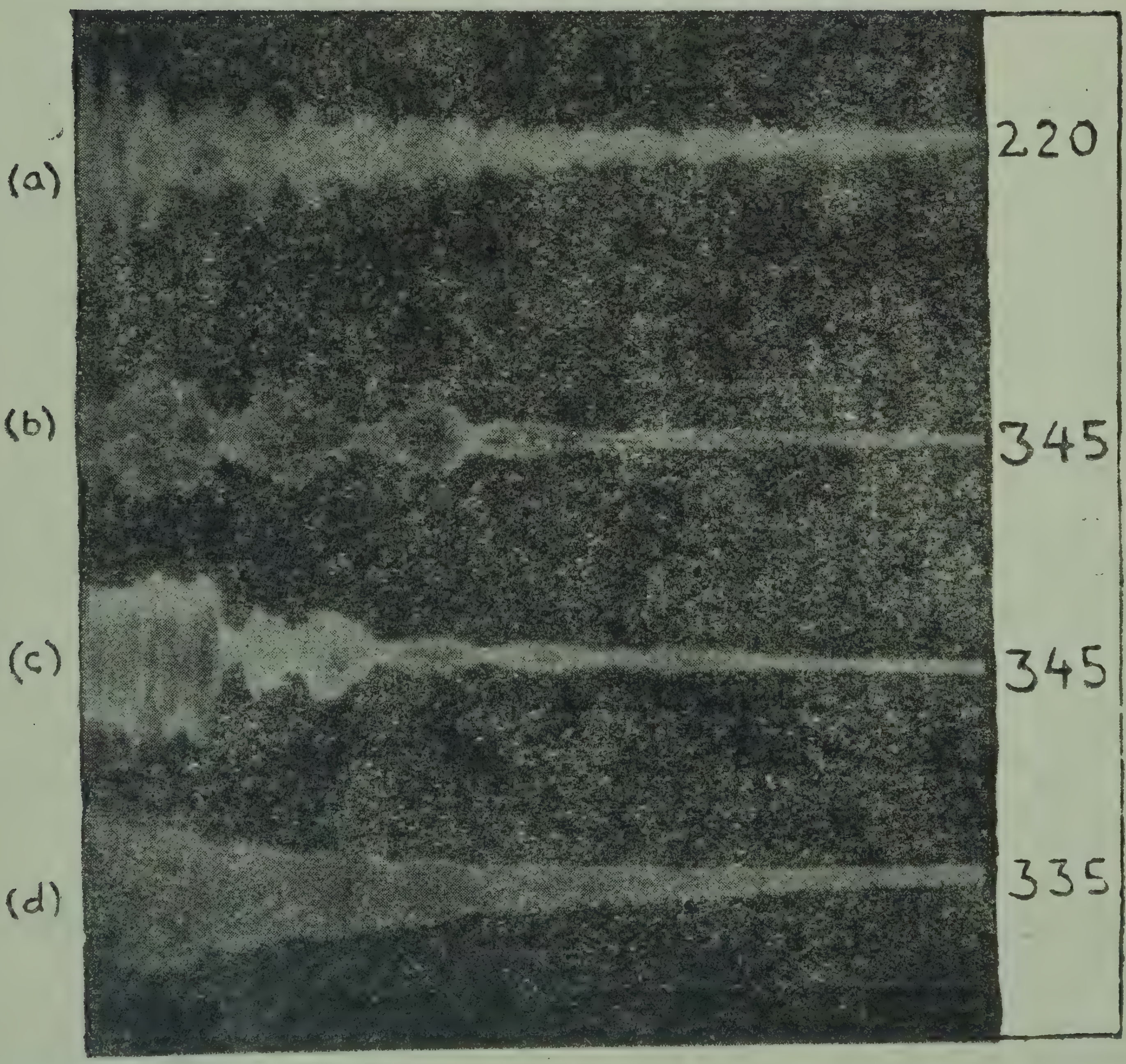
$$V_l = V/\sin\theta_l, \; V_s = V/\sin\theta_s.$$

The method has been made possible through the pulse technique now available. Pulses short at 2.5 M.C. are generated at regular intervals and sent into the liquid by an x cut quartz crystal, and the transmitted pulses are received by a similar crystal and the incident pulse, the transmitted one are fed into a cathode ray tube. Fig. 7 shows the phenomenon. In addition to the first transmitted pulse, we have other pulses reflected between the solid and the boundary walls of the liquid, and also internally reflected pulses.

A graph of amplitude of the transmitted pulse against the angle of incidence is shown in Fig. 8. The first dip is due to longitudinal wave and the final fall is due to the total reflection of shear wave.

Work on jellies and colloidal solutions are in progress. It will be noted that all these results verify C. G. Knott's theory of regarding the breaking of a wave into longitudinal and shear waves when a wave is incident on the surface of a solid medium.




(a)
220
(b)
345
(c)
345
(d)
335

TABLE

No.	Substance	Density	Tank liquid	$V \times 10^{-5}$ cm/sec	$V_e \times 10^{-5}$ cm/sec	$V_s \times 10^{-5}$ cm/sec	$n \times 10^{-11}$ dynes, Cm^2	$E \times 10^{-12}$ dynes/cm^2	μ
1.	ALUMINIUM	2.70	WATER	1.5	7.2	2.83	2.16	.609	.406
2.	BRASS	8.54	WATER	1.5	4.5	2.33	4.64	1.22	.317
3.	IRON	7.86	WATER	1.5	6.1	2.85	6.38	1.78	.361
4.	BLACK STONE from MALABAR (South India)	2.99	WATER	1.5	7.23	3.84	4.41	1.15	.303

I have completed adress. I have not been able to do justice to many important contributions of other workers on account of shortness of time. But you will agree with me that the Indians contributed even in this much neglected subject. I feel if some high class young mathematician were drawn into this branch of physics, progress would be much more. There is certainly death of indegenous apparatus. We have been working with crude and improvised apparatus that could be made in India in comparison to the immense facilities in other countries. Much valuable work has been done in this direction by Dr. N. B. Bhatt and Shri D. L. Subrahmaniam; the construction and design of logarithmic amplifier for reverberation measurement and reverberograph sound level meter by these workers represents a land mark, and is hoped that others will take the lead given by them. The time has come that we make our own apparatus not only for our laboratory use but for general public and industrial uses. The talents of the young scientists should now be directed to the perfection of instruments.

In his Electro-acoustic Laboratory at the Indian Institute of Science Bangalore, Dr. Bhatt and his associates have not only constructed equipments like the Sound Level Meter and Reverberation Time Meter but also have designed and developed new equipment.

All these equipments have been constructed from components easily available in any electronic laboratory. The Sound Level Meter conform strictly to the specifications of the American Standards Association. It employs a moving coil microphone instead of a Crystal microphone as is usually done in commerical instruments ; this makes the equipment better suited for tropical countries, where the crystal microphone looses its sensitivity and becomes inactive. A new type of calibrating the Sound Level Meter is also developed. Much work still remains to be done in this direction. Thank you gentlemen.

REFERENCES

1. F. A. Saunders *J. A. S. A.* 9, 82, (1937)
2. S. K. Banerjee. *Phil. Mag.* 32, 96, (1916).
3. C. V. Raman. *Proc. Ind. Acad. Sci.* 4, 179 (1934).
4. Raman and Nagendra Nath. *Proc. Ind. Acad. Sci.* 4, 2, 406 (1935)
5. S. Parthasarathy. *Proc. Ind. Acad. Sci.* 3, 442 (1936)
6. Eyring C.F. *J. A. S. A.* 1, 217 (1930)
7. N. B. Bhatt. *J. A. S. A.* 11, 65 (1939)
8. P. M. Morse, *Rev. Mod. Phys.* 16, 101 (1944)
9. C. M. Harris, *J. A. S. A.* 17, 36 (1945)
10. DAH-YOV-MAA. *J. A. S. A.* 12, 242, (1940)
11. C. M. Harris, *J. A. S. A.* 17, 242 (1946)
12. P. M. Morse *Rev. Mod. Phys.* 16, 134 (1944)
13. Haji Gulam Mohammad. *Proc Nat. Inst. Sci.* (Indian) 4, 316 (1938)
14. Chandrakanta (Miss), *Proc. Nat. Inst. Sci.* (India) 6, 671 (1940)
15. LEO L. Beranek, *J. A S. A.* 12, 3 (1940)
16. J. C. Hubbard *Phys. Rev.* 41 (1932)
17. A. K. Dutta, *Trans. Rose, Res. Inst.*(13) 31 (1937-39)
18. R. Fruth, *Proc. Camb. Phil. Soc.* (1941)
9. C. G. Knott, *Phil. Mag.* (1898).

37th INDIAN SCIENCE CONGRESS, POONA, 1950

SECTION OF CHEMISTRY

PRESIDENT: DR. J. K. CHOWDHURY, Ph.D., F.N.I.

Presidential Address

THE UTILIZATION AND DISPOSAL OF INDUSTRIAL WASTES

THE NEED FOR A NATIONAL PROGRAMME

It is a great honour and privilege to be elected President of the Chemistry Section, the largest and perhaps the most important section of this premier scientific organisation, meeting in this historic city of Poona. This honour would have been more enjoyable, had it not carried with it the obligation of delivering a presidential address. The selection of a suitable subject has been a problem to me. It was not easy to choose between a specialised branch of knowledge and one of general interest. After some hesitation, I have decided to speak to-day on the 'utilization and disposal of industrial wastes', partly because of the importance of the subject for public welfare and partly because it does not appear to have received the attention it deserves in this country. With the likelihood of great industrial expansion in the immediate future, this subject also appears to be an opportune one at the present moment.

"Waste" is perhaps not an appropriate word to use. What is waste to-day may be a by-product of considerable value tomorrow. It is well-known that in the case of coal carbonisation, the by-products have become more important than the main product. A typical example of our continued change of the idea of value is furnished by monazite sand which occurs in large amounts in the sea coasts of Travancore and was once considered to be a mineral of no value at all. On account of its high specific gravity, it was used as ships' ballast in their return journey from India. The discovery of Auer von Welschbach first drew the attention of the world to monazite sand as a source of thorium for the manufacture of gas mantles. The use of cerium as an alloying metal further increased its importance. The development of atomic energy has now turned all attention to thorium—an element very similar to uranium in atomic structure and to-day monazite sand is considered as a strategic mineral of national importance.

Utilization of low grade materials for the production of valuable articles is one of the proudest achievements of chemistry. Although conversion of base metals into gold is no longer the aim of the modern chemist, he is still guided by the basic idea of obtaining more costly materials from less costly ones. In this attempt, impurities in the raw material, reinforced by various amounts of chemicals and other materials added during the process of extraction, form large amounts of waste products in solid, liquid or gaseous state. In quantity these waste materials often outweigh the valuable product. Solid wastes are usually dumped in low lands and often become a nuisance to the locality. Gaseous wastes, unless harnessed for use, may cause considerable injury to health and property. In solution or suspension in water, they serve to pollute streams and rivers, and constitute a danger not only to aquatic life but also to the inhabitants of the area.

The impending industrialisation of the country, concentration of industries in certain areas and the increase of urban and industrial population will further aggravate the trouble. It is the responsibility of the industries to deal suitably with the waste problem which is their own creation. It appears that industries in western countries are now quite alive to this responsibility. Superior technical staff, formerly employed on problems of production, is being increasingly diverted to tackle problems of pollution ; adequate financial provisions are made for the construction and working of costly plants with a view to recover marketable products and dispose of the residues in a harmless manner.

The utilization of waste materials depends largely on the cost of the processes involved and on the cost of collection. Where the operation is profitable, by-products are recovered without much difficulty. Sometimes the waste of one industry is used as a raw material in a sister industry. In this way a group of interdependent industries spring up in certain areas. Where the operation may 'break even', without bringing any reasonable gain or may involve a slight loss, private enterprise is naturally reluctant to come in. It should however be remembered that the responsibility of eliminating the waste primarily rests on the industry which generates it. The cost involved in reclamation and disposal processes should form an integral part of the industry as a whole and should be taken into account in fixing the price of different products. In no case should such operation be regarded as an isolated industrial unit. If the cost of equipment and other expenses be too heavy for any particular industry, it would be open for the state to extend a helping hand and offer such financial and technical assistance as will meet the situation.

The value of an undertaking should not be judged from the point of view of profit alone when it happens to play an important role in our national economy or general welfare. Considering the size and population of the country, India is relatively poor in the supply of many important raw materials. Our natural resources for the supply of sulphur, fertilisers, mineral oils and many important metals such as lead, zinc, cadmium, vanadium, molybdemum etc. are far from satisfactory It is therefore imperative that we should try to widen our raw material position. Formerly this was done through wars of conquest or through the exploitation of backward people. Science has opened up new methods more potent than older ones.

RECOVERY OF SULPHUR

A short survey of the methods of recovery of sulphur and a few other important materials will illustrate the point in issue. Sulphur occurs as sulphuretted hydrogen in various fuel gases. In the purification of these gases, sulphuretted hydrogen has to be removed almost completely. Sulphur also occurs as sulphur dioxide generated in the combustion of coal and in the smelting of sulphurous ores. When discharged into the atmosphere, it causes considerable damage to vegetable life, industrial plants and household equipments.

Recovery and utilization of sulphuretted hydrogen.

In the drive for national self-sufficiency, recovery of sulphur as a by-product has been practised on a large scale in Germany. Reclamation measures have succeeded in making the country largely independent of foreign supplies. Coke oven gas, low temperature carbonisation gas, synthesis gas and gases evolved in coal hydrogenation were used for the extraction of sulphur. The following figures of the production of elementary sulphur in Germany are illuminating:

1927	10,000 tons
1937	32,000 tons
1938	50,000 tons
1939	70,000-80,000 tons (estimated)
1941	180,000-190,000 tons („)

The enormous increase in the production of synthetic oils in Germany during the war years was accompanied by corresponding increase in the production of sulphur. In U.S.A. inspite of the occurance of extensive deposits of natural sulphur, recovery of byproduct sulphur has been practised on a large scale. Here natural and refinery gases form the greatest source of sulphuretted hydrogen. It has been estimated that in 1939, U.S.A. produced abcut 50,000 tons byproduct sulphur of which nearly 10,000 tons were in elementary form and the remaining 40,000 tons as sulphuretted hydrogen converted directly into sulphuric acid.(7)

In recovering sulphuretted hydrogen from various gases, two types of processes are generally used—the dry processes and the wet processes. Although numerous processes have been developed, coke oven gases are still refined by the traditional process of passing the gases through hydrated iron oxide. The efficiency of absorption falls considerably when the S-content reaches 40-50%. In Germany this sulphur is extracted with carbon disulphide, though the operation is not economic and the sulphur has to be further purified. In U. S. A., no use is made of this spent oxide, while in England it is used to some extent for the manufacture of sulphuric acid. On the whole it can be said that no economic and satisfactory use has yet been found for the vast mass of spent-oxide used in refining fuel gases.

In Germany synthesis gases are purified also by the use of activated carbon for the catalytic oxidation of sulphuretted hydrogen to sulphur, which is then extracted with suitable solvents. Formation of tarry matter and consequent loss of activity of the active carbon have limited the usefulness of this process. It has been claimed that special types of activated carbon, free from these defects, have been successfully evolved in Germany.

For the recovery of sulphur, wet processes are more suitable than dry processes. The final removal of traces of the sulphur compound by these processes is rather costly and hence these processes are usually followed by iron oxide refining. Recent development of two stage wet processes, however, permits almost complete removal of H_2S without substantial increase in cost. These wet processes may be classified in the following three groups:

(*i*) When ammonia is present in the fuel gases, ammonium sulphate and sulphur are recovered in one operation, involving oxidation of sulphuretted hydrogen to sulphur by air or other oxidising agents.

(*ii*) Oxidation of sulphuretter hydrogen is brought about in solutions by a chemical reagent which is thereby reduced and is regenerated by the blowing of air. Sulphur in finely divided particles, usually in the form of slurry, is obtained by these processes.

(*iii*) Sulphuretted hydrogen is absorbed in suitable solutions at a low temperature and is then expelled in the heat as practically pure H_2S. It is then converted either into sulphuric acid if there is demand for it in the neighbourhood or into elementary sulphur if it is intended to tap a wider market.

The Katasulf and the Kohlentechnik processes (1) both developed in Germany are typical representative of class (*i*) processes. Though special advantages are claimed, actual production of sulphur and ammonium sulphate by these processes does not appear to be great. The Thylox process and the Staatsmijnen—Otto process are typical representatives of class (*ii*). The Thylox process uses a solution of sodium thioarsenate containing 0.7% As_2O_3 and maintained slightly alkaline (pH 7.6-8.0) for the absorption of H_2S. The solution is then pumped to a tall tower where it is regenerated by blowing air and the sulphur is 'floated' to the top and filtered. The sulphur-cake however contains large amount of water. By the use of the two stage Thylox process, almost complete removal of H_2S may be secured without substantial increase in the cost of operation. More than two dozen plants of this type are in operation in U.S.A., Germany and Japan. All kinds of fuel gases are said to be amenable to treatment by this process.

The Staatsmijnen-Otto process (4) uses ferric-ferrocyanide solution for the absorption of H_2S. The ferrous salt formed in the reaction is regenerated to original form by passing air when it becomes suitable for reuse, while the sulphur is carried upwards as a foam or paste. The non-poisonous character of the solution and the higher purity of sulphur make this process attractive. The nickel process (10) also claims high efficiency and purity of sulphur and is successfully used in several plants in U.S.A.

The phenolate process developed by Koppers in U.S.A. and the Alkazid process developed by I.G. in Germany are typical representatives of class (*iii*) processes. A few other processes using aromatic amines, suspension of Magnesium hydroxide in water, solution of sodium or potassium borate and phosphates have also given promising results.

The phenolate process (7), as the name indicates, uses a concentrated solution of sodium phenolate, in which the proportion of sodium and phenolate radicals may vary within wide limits. Sulphuretted hydrogen is absorbed at a low temperature (25°C), when evidently it is the stronger acid than phenol. At the regeneration stage, when this foul solution is heated to boiling temperature, the phenol becomes the stronger acid and therefore drives out H_2S from the solution. This process is operated either in single stage or in two-stage processes. When it is intended to remove, say, 90% of H_2S in a gas, the one-stage process has been found more economic. When complete removal of H_2S is desired, steam consumption (12.0 lbs.) by the single stage process is rather excessive. In such a case, two-stage process has been found economic, as it requires only 3.5 lbs. steam per lb. of H_2S recovered. This process is usually followed in U.S.A. for refinery and natural gases which are normally worked under high pressure. But it may also be adapted for low pressure and low sulphur gases such as the coke oven gas. Two Oil Companies of U.S.A. the Altantic Refining Co. of Philadelphia and the Standard Oil Co. of California, are reported to be treating more than 55 million cu.ft. of such gas per day, recovering more than 26,000 tons of sulphur per annum.

The alkazid process (8) uses water solution of alkali or alkaline earth salts of certain amino acids (e.g. glycocoll or alanine) for the absorption of H_2S which is absorbed in the cold and expelled by heat, thus regenerating the solution for fresh use. This process is extensively used in Germany and is responsible for the production of more than 30,000 tons of sulphur annually (1939).

The Girdler process uses a concentrated solution of mono, di and tri-ethanol amines in water to absorb sulphuretted hydrogen. This process is largely used to recover carbon dioxide from flue gases. Several plants for the manufacture of dry ice are operating this process in U.S.A.

The pure sulphuretted hydrogen gas generated by the above processes is either converted into sulphuric acid by the catalytic process or to elementary sulphur by oxidation in Claus furnace improved by I.G. (8) using bauxite or some other catalysts (5). For the purpose of conversion into sulphuric acid, H_2S, is oxidised to SO_2 and H_2O, freed from water vapour and the dry sulphur dioxide converted to sulphuric acid by the usual contact process. In recent years, Lurgi Chemie has developed the wet catalytic process which eliminates the step of removing water vapour. The wet SO_2 gases are passed directly over the contact mass and the products are cooled by condenser without formation of mist. This process is in operation in several plants in Germany and England.

As numerous new processes for the extraction of sulphur are coming to the fore and as constant improvements are being made in old ones, it is difficult to form a clear idea of the comparative merits of different processes. The following table (1) based evidently on data of the working of 1937 will give some idea of the relative importance of the processes followed in Germany.

Process	Range of optimum S-content in gas g/m^3	Type of gas used	Amount of S recovered (tons)
1. Dry process using Fe_2O_3	7-12	Coal gas	14,000
2. -do- active carbon	3-4	Synthesis gas	10,000
3. Kohlentechnik	8-12	Coke oven gas	
4. Thylox	7-15	-do-	4,500
5. Girdler	above 10	-do-	
6. Phenolate	above 10	-do-	..
7. Alkazid	above 10	Coke oven and synthesis	17,000*
8. Katasulf		Coke oven	1,000

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*This figure is reported to have increased to 30,000 tons in 1939.

Utilization of waste sulphur dioxide.

Vast quantities of sulphur is lost as sulphur dioxide generated by the combustion of coal and by the smelting of sulphur-bearing ores. When the concentration of sulphur dioxide is high (7% or more), as is the case with the roasting of pyrites and zinc ore, the utilization does not present any special difficulty. The concentration of the gas generated in several roasting operations, however, falls considerably below this figure and often lies between 0.5 and 2%,—a concentration in which sulphur was not thought to be recoverable. The concentration of sulphur dioxide in industrial flue gases is even lower and varies considerably with the sulphur content of coal. The sulphur dioxide evolved in these operations has injurious effects on animal and vegetable life and is responsible for considerable economic loss caused by the corrosion of metallic parts of industrial and household equipments.

During the last decade, substantial progress has been made in the recovery and utilization of sulphur dioxide and a large number of processes claims success in this field. The essential principle in all these processes is, first, to strip sulphur dioxide from dilute gases by means of absorbents and then to release the gas in concentrated form usually by the action of heat. The concentrated sulphur dioxide is then used for the manufacture of sulphuric acid, paper pulp and other industrial purposes. It is also reduced to elementary sulphur, in which form it serves a much wider market and can be easily transported.

Although a large number of processes have been developed in recent years, only a few of the more important ones are mentioned here:

(*i*) At Trail, Canada, the Consolidated Mining and Smelting Co. uses ammonia as the primary absorbent. In this process sulphur dioxide is absorbed in scrubbing towers until a strong solution of ammonium bisulphite with some normal sulphite is obtained. It is then treated with sulphuric acid, forming ammonium sulphate and releasing sulphur dioxide in concentrated form. This sulphur dioxide may either be used for sulphuric acid and other industrial operations or may be reduced to elementary sulphur according to market demand. Nearly 200 tons of sulphur is produced in this plant per day. In Germany, the Metalgesellschaft A.G. (8) has been successful in preparing ammonium sulphate by reacting a mixture of these dilute gases and air with finely dispersed ammonia, thus avoiding the consumption of sulphuric acid.

(*ii*) An excellent process, known as the sulfidine process, has been developed by Lurgi Chemie in Germany (11). A water suspension of some aromatic amines is used as absorbent. As sulphur dioxide is absorbed, the sulphite goes into solution. When heated to 80-100° C, pure sulphur dioxide is given off and the absorbent separates again to form an insoluble layer and is reused. This process has high efficiency and is in successful operation in Germany. Sulfidine solutions are selective in their absorption capacity, sulphur dioxide being preferably absorbed from a mixture of the gas with carbon dioxide (*iii*) The Imperial Chemical Industry's process (Billingham, U.K.) uses basic aluminium sulphate as absorbent and almost pure sulphur dioxide is expelled by heat.

The reduction of sulphur dioxide into sulphur is usually carried out either by (a) the Bolidens process (7) of catalytic reduction with gases from coke fired furnaces or by (b) the two stage reduction process of I.G. (11) in which sulphur dioxide is reduced first at 900°–1200° C with coke and the gaseous products are again heated with sulphur dioxide at 500°-700° C when they are freed from COS and CS_2, yielding elementary sulphur and carbon dioxide.

India's present requirement of sulphur is about 45000-50000 tons per annum and is met wholly by import. Next to soda ash and caustic soda, it stands highest in import value. Foreign currency worth more than rupees 50 lakhs would be saved if the country's requirements could be met internally. There are vast deposits of sulphur-containing coals in Assam, in which sulphur content is nearly 4% on an average. It is generally consumed in furnaces with large excess of air. As a result, the concentration of SO_2 in flue gases is rather low and lies between 0.2 and 0.5% by volume. In improved furnaces using less excess of air for combustion, the concentration is considerably higher. Low as this concentration is, it is still recoverable with the help of modern methods. If this coal were subjected to low temperature carbonisation or to hydrogenation processes, either directly or by the Fischer-Tropsch process, the concentration of sulphuretted hydrogen would be very high and economic recovery of sulphur would be practicable. It is interesting to note that British Power Plants have been treating concentrations of .05-.2% sulphur dioxide with 99.7% efficiency (18).

It has been stated that about 20 tons of sulphur is lost every day as sulphur dioxide, produced in the smelting of chalcopyrites in Singhbhum district. It is worth while to explore the possibility of its utilization. The synthetic ammonia plant at Sindri, situated not very far from Singhbhum, has opened up new possibility of its utilization by the Canadian or German processes. It should not be too costly to transport ammonia from Sindri to Ghatsila (Singhbhum). If the sulfidine process or I.C.I. process is found to be more suitable, sulphur dioxide recovered at Ghatsila, could be transported without much difficulty in the reverse direction for conversion into ammonium sulphate at Sindri by the Maschinengesellschaft or other processes. At present, the production of ammonium sulphate in the Sindri plant is dependent on distant sources of gypsum. The development of an alternative process would impart greater flexibility to the Sindri plant which could switch over to either of the processes according to circumstances.

RECOVERY OF PHENOL FROM WASTE WATER

At present India imports about Rs. 28,000 worth of phenol but this low consumption does not fully reveal the commercial importance of this product. The expansion of the chemical, pharmaceutical and munition industries in this country, the manufacture of plastics and herbicides of the plant hormone type will create considerably greater demand. The waste water of coal carbonisation and tar distillation industries carry considerable amounts of phenol into the river system. Even a very small concentration imparts repugnant taste and odour to water. When drinking water is chlorinated, it results in the formation of p-chlorophenol which, even in great dilution (.02 p. p. m.), imparts a characteristic medicinal taste, so familiar to many of us. While phenol is slowly destroyed by the natural process of oxidation, the p-chloro compound is resistant to such oxidation and this explains the persistence of the taste in chlorinated drinking water. When concentration of phenol in waste water is low (1-30 p.p.m.), it is easily destroyed by biological processes of oxidation. Such waste water is usually led into the sewers and no attempt is made to recover phenol. The concentration may however rise to a considerable extent. Ammonia still wastes, for example, have been found to contain 1000-2500 p.p.m. of phenol. Phenol may be removed from such water by extraction with benzene and other solvents from which it is recovered by treatment with alkali and the solvent reintroduced into the process. The absorption capacity of tricresyl phosphate for cresols and phenol has been found to be much greater than that of benzene. The recovered phenol is however impure, contains high boiling fractions and has to be refined before use. In 1937 the German plastic industry used 30,000 tons of phenol of which 5000 tons were reclaimed material.

A process by which phenol is recovered in a purer state has been developed in U.S.A. (3). In this process ammonia liquor is first freed from CO_2 and H_2S in the upper section of the conventional ammonia still and is then passed into a dephenoliser,—a packed tower where it comes into contact with steam. The steam carrying the phenol passes into a second tower where it is scrubbed with caustic soda solution maintained at suitable temperature to prevent dilution. The liquor from the first tower goes to ammonia recovery plant, while the alkaline extract from the 2nd tower is treated for phenol recovery. The quality of this phenol is said to be exceptionally good.

EXPLOITATION OF MUNICIPAL WASTES

Municipal wastes primarily consist of (*a*) street and domestic refuse and (*b*) sewage. The rapid growth of urban population has led to enormous increase in both these wastes and their satisfactory disposal has become a problem. In recent years, considerable progress has been made in the rational utilization of these wastes. For this purpose, the refuse matter and sewage are generally treated separately, although in a few instances, mixtures of organic refuse and sewage have been used.

Municipal Refuse

The primitive method of using refuse matter to fill up low lands and ditches is still followed in several towns. But the obnoxious odours and hygienic considerations have rightly brought such use into disfavour. Incineration has been practised in several towns and later attempts were made to utilize the calorific value for raising steam and generating electricity. The low calorific value of these waste materials is further lowered by the presence of moisture and inorganic matter such as ash, concrete etc. and hence their utilization as fuel is not a simple matter. The residual ash from these fuels has been used as an excellent road building material. Mixed with cement, this ash has given artificial stones used for pavements and buildings.

Attempts were made to gasify refuse matter in producer gas generators and to subject it to low temperature carbonisation. Several other uses have been tried *e.g.*, manufacture of fuel briquettes and preparation of light building materials by pressure. None of these processes seems to have found favour in large scale practice.

Rational utilization of refuse matter must be based on its composition which varies within wide limits. The inorganic matter consists of useful materials such as tins, metal scrap, glass etc. and less useful materials such as stone and brick chips, kitchen ash and the like. The organic matter consists of rags, paper, bones, rubber, cooked food and sweepings of houses and streets.

Sorting is the basis of modern utilization processes. Female labour is usually employed for picking up more useful materials such as tin vessels, scrap iron, non-ferrous metals, paper, rags, glass, rubber and similar articles. These materials are then despatched to appropriate industries which use them as raw materials. In 1936, the city of Berlin collected 10,000 tons of these useful materials from street refuse, valued at R.M. 270,000. In 1937, sorting of refuse was enforced in all German towns with a population of 35,000 or more and huge quantities of useful materials were reclaimed. To mention only one item, about 280,000 tons of rags were collected in that year (2).

The residual organic matter, left after sorting contains nitrogen, phosphorus, potassium and calcium. When added to the soil, it not only supplies these plant nutrients but also the organic matter which decomposes into humus, retains moisture in the dry season and improves soil texture. Formerly, the usual method was to spread it on the soil and plough it in. Later this practice was improved, *e.g.* in Barren islands U. S. A. where the refuse was steamed for several hours in closed vessels, fat and water removed and the residual solid matter dried, crushed and sold as artificial manure. It was found that fresh refuse led to heavy incidence of disease and crops susceptible to salts suffered most. With time, however, the organic matter weathered and improved the ability of soil to hold water. The time required for this ageing process was too long and various artificial processes of ageing or 'composting' were developed to accelerate the process. The Beccari process was carried out in closed chambers, accompanied by a rise of temperature and required about 38 days. At the Hague, where the refuse was stacked in heaps, it required 2-3 months. At Salzburg, the refuse was mixed with sewage and ripened in beds under anaerobic conditions. A similar process developed by C. N. Acharya is followed by several municipalities in India and yields a product of high fertilising value. The process followed by the Royal Borough of Kensington is a typical example of these biological processes and may be briefly described here (15).

The refuse is dumped into large pits screened to prevent egress of dust. It is then conveyed mechanically to the top of a few towers whence it passes to belt conveyors. Here articles such as metals, papers, rags, glass etc, are picked out by hand. It then goes to rotating cylindrical crushers, screened, sprayed with bacterial cultures and conveyed to closed chambers, where it undergoes fermentation—anaerobic and aerobic—for a period of about sixteen days. The temperature rises to 170—175° F, gases are removed through flues and may be utilized as fuel. The nitrogen content of the residue varies from 0.97—1.42 per cent (average 1.16%) and its moisture content is only 30%. At Rothamsted, this manure has been tried for several crops under various conditions of soil and it has been found superior to cowdung for the same nitrogen content.

Sewage

In the larger towns provided with sewage system, huge quantities of this 'nuisance' have to be disposed of in a hygienic manner. This task imposes a heavy financial burden on the municipal authorities. A close examination of the nature and composition of sewage revealed that it had economic possibilities and the idea of combining disposal of sewage with its economic exploitation gained strength.

Sewage consists of a mixture of human excreta, city's drainage and industrial effluents. Human excreta consists of a large quantity of organic matter in addition to plant nutrients like nitrogen, phosphorus and potassium. As sewage contains other materials besides human excreta, its analysis differs considerably. In addition, it contains numerous bacteria, fungi and other micro-organisms. A good method of utilization should take this fact into account and should make proper use of these micro-organisms.

Originally sewage was discharged into rivers and streams without any previous treament. Here they underwent a process of self-purifiction—a part of the material dissolved in water and was oxidised by air, a part was acted on by bacteria forming gases, sediments and soluble substances and a part formed insoluble sludge. The capacity of rivers for this self-purification process is limited and depends on the volume and flow of water, which vary greatly according to season. In many instances, the water becomes seriously polluted. Later some improvement followed when the solid sludge was separated by sedimentation before leading the overflow effluents into the rivers. Fermentation of the sludge in tanks, and the soluble organic matter and micro-organisms discharged into the rivers, however, created a situation difficult to deal with.

Then followed attempts to combine disposal of sewage with its utilization for agriculture. The raw sewage was carried to distant fields in pipes and exposed to the weather. In the course of the ageing process which followed, the organic matter slowly decomposed to form humus which retained moisture in the dry season and provided an abode for soil micro-organisms. Nutrients such as nitrogen, phosphorous and potassium also contributed towards soil fertility. It has, however, been found that weather conditions play an important role in this process and only porous soils permit aeration and stimulate the growth of soil micro-organisms. If too much sewage is used, the soil becomes exposed to the danger of sludging or poisoning commonly known as 'soil sickness'. The sewage of 100 people per hectare (2.47 acre) has been found to be the optimum amount for sandy soils in Germany (2). The danger of bacterial infection and persistent odour makes green manuring unsuitable for the cultivation of vegetables. Cultivation of albumin-rich crops has given promising results and the protein content of hay, grown on land treated in this way, is reported to be much higher than that of hay grown on untreated land. Subrahmanian has found that sugarcane responds well to raw sewage but technological implications of the increase of non-sugars in canes have yet to be investigated. Owing to the unhygienic nature of such manuring and the limited types of soils which respond to it, this method has not been widely accepted. Moreover, the nitrogen occurs in organic form and is only partly available to crops. The distribution system requires laying of costly pipe lines and pumping stations, and absorbs a large capital.

The natural biological processes involved in the self-purification process can be stimulated by artificial means. For this purpose numerous bacteria, aerobic and anaerobic, already present in sewage are made use of. While aerobic fermentation converts organic matter into carbon dioxide and water, anaerobic fermentation produces methane and carbon dioxide to the extent of about 95%, of which about 70% is methane. The remaining 5% consists of hydrogen, sulphuretted hydrogen, and traces of oxgen and nitrogen. After purification, this gas may be used for heating fermentation chambers, generation of power and propulsion of motor vehicles. The evolution of low weight, high pressure alloy cylinders has enabled the use of this gas as petrol substitute. One cubic meter of the gas is equivalent to 1 liter of petrol. It has been estimated that 4-5 per cent of Germany's petrol requirement could be met from this source.

Anaerobic fermentation is decidedly cheaper than aerobic. It is carried out in closed chambers maintained at optimum temperature and provided with exit pipes for gases. The final effluents still contain considerable amount of organic matter and have unpleasant colour and odour. It should be further refined by aerobic fermentation before discharging into streams. Two types of processes are usually followed for this purpose—(*i*) trickle filters and (*ii*) tanks provided with air diffusion (activated sludge process). The former requires a large capital and low recurring expenditure while the reverse is the case with the latter. The final effluents in both cases have low colour, odour and pollution load. The general trend of opinion seems to be in favour of the trickle filter process. The final effluents are chlorinated and discharged into the irrigation system. There is however strong prejudice against this effluent being led into the canal water. For this reason, a closed system has been developed, in which the soluble organic matter is coagulated with the help of chemicals and after settling, the final effluent is reused in the fermentation process. The sludge obtained from the aerobic fermentation process consists largely of bacterial protoplasm and has high nutritive value as manure. The water content (about 85%) is lowered to about 50% by dehydration before putting it in the market as manure. This biological decomposition has provided a hygienic method for the disposal of sewage, combined with its utilization for agricultural purposes. Simultaneously a part of the calorific value can be utilized for industrial purposes in the form of fuel gases.

All organic matter, whatever its nature, can be decomposed by biological processes, although the composition of the products will depend on the nature of the organic matter and on the process of fermentation. Industrial effluents carrying organic matter can therefore be mixed with sewage after adjustment of pH and then subjected to biological treatment. Effluents from textile mills, tanneries, slaughter houses and organic chemical industries may be treated in this way before their final discharge into the river system (6). Disinfectants must be highly diluted before mixing them up with sewage.

UTILIZATION OF OTHER INDUSTRIAL WASTES

Coal Wastes

It is well known that India has practically unlimited reserve of low grade coals but those with more than 25% ash content are usually regarded as unworkable. Large quantities of coal dusts which accumulate at pitheads do not find adequate use. Pressure combustion of powdered coal, development of slag-trap furnaces for boilers and introduction of washing processes have opened up new possibilities of economic exploitation of high-ash coals and have created a new demand for waste coal dust. Considerable quantities of these 'dusts' accumulated at pit-heads, are carried away by rain water into low lands and streams. This loss can be controlled by collecting the water in ponds, where the coal particles are settled before leading the clear overflow water into the streams. The colloidal sludge collected in coal washing plants is rich in organic matter and trace elements, and is reported to be highly suitable for amelioration of soils and control of difficiency diseases in plants.

The ash content of coal constitutes a huge waste for which no satisfactory use has yet been found. The principal components of the ash—silica, alumina and ferric oxide—account for 80-90% while other constituents—lime, magnesia, oxides of manganese and alkali metals together with some sulphate and phosphate radicals account for another 7-15%. This leaves a difference of 2-3 per cent, which is accounted for by a large number of elements present in very small amounts. These elements may be classified as follows:—

(*a*) Rare metals, *e.g.* beryllium, germanium, zirconium, gallium etc.

(*b*) Trace elements, *e.g.* copper, nickel, cobalt, vanadium, molybdenum etc.

(*c*) Precious metals, *e.g.* gold, silver, platinum etc.

These elements owe their origin to the plant life which sucks them up from the soil and thereby concentrates them to a considerable extent. In the natural process of decomposition involved in the formation of coal, these elements are further concentrated in coal deposits. In the process of combustion of coal, they are still further concentrated, giving rise to appreciable amounts in the ash residues. Mukherjee and Dutt (20) have subjected Indian coal ash from different sources to spectrographic analysis and detected the presence in appreciable amounts of several of these elements. According to the authors, 0.1% germanium is present in the ash of Garro Hill coals, which is considered to be one of the best tapping sources for the extraction of germanium in India. It is however doubtful if exploitation of only one element, however valuable, from coal ash would prove economically feasible. For this purpose, total explotation should be aimed at, extracting not only the valuable metals but also utilizing the residues to the best possible advantage. It should be possible to effect magnetic separation of iron oxide in the ash and to convert the residual matter, mixed with limestone, into cement. Such a process of total exploitation will however have to await the solution of technical difficulties involved in the metallurgy of low grade materials.

The by-products of the coal carbonisation and tar distillation industries are too well known to need any mention here. Nor is it intended to deal with synthetic oil made from coal, inspite of its importance for the preparation of a wide variety of chemicals and other products.

Metallurgical Wastes

Modern metallurgical methods have enabled exploitation of low grade ores on the one hand and reduction of slag and flue losses on the other. Two processes for the dressing of ores have met with particular success, *e.g.*, (*i*) sink-and-float-process and (*ii*) flotation process. The flotation method is used to-day in widely different fields. It has been used for the recovery of gold that has escaped the cyanide process, for the working of lead and zinc slimes, for the concentration of copper in low grade ores, for the recovery of molybdenum ores and for several other purposes.

Introduction of improved methods of metallurgy have resulted in the utilization of low grade materials. In Europe, large number of abundoned mines whose working was regarded as unprofitable, has been reopened and is now working successfully. Residues from dressing and smelting processes, which were dumped into waste heaps, are now re-exploited and large quantities of metals are recovered from them. Thus zinc ores containing pyrites and bauxite rich in iron are charged in ordinary blast furnace and in the case of the former, zinc is recovered from flue dust and in the case of the latter, the presence of aluminium makes the slag suitable for high grade cement. The use of iron ore containing only 30% or even less of iron, for the production of pig iron and of clay, for the production of metallic aluminium, are other instances of the use of low grade materials in modern metallurgy.

Cooling of smelter gases and introduction of Cottrell precipitators have led to the recovery of many important by-products from smelting furnaces. The nature and quantity of these by-products depend on the nature and degree of impurities present in the ore. Reference has already been made to the recovery of sulphur. Arsenic and cadmium have been recovered in large amounts from flue dust in the smelting of copper and zinc ores. The use of the flue dust separated by the electrostatic methods, depends on its chemical composition. Many other elements such as bismuth, antimony, vanadium and selenium have been obtained from it. Flue dust from blast furnaces and cement works have been sent back into the process and reused after appropriate treatment. There is increasing tendency to use the wet electrolytic process for the production of zinc. This process also enables better recovery of associated metals which are present in the sludge and may be recovered from it. Mention may also be made of the 'red mud' which separates in the purification of bauxite by the Bayer Process and accumulates in large quantities in aluminium factories. In India, this mud is particularly rich in titanium whose extraction has been studied by several investigators (14).

Slag:

Vast quantities of slag are produced in ferrous and nonferrous metallurgy. Roughly speaking, for the production of every ton of pig iron, there is half a ton of slag produced. Proper utilization of these slags is an important problem and attempts in that direction have been only partly successful. Slag wool has ben produced by injecting steam into the molten mass and this wool has been extensively used for house insulation, refrigeration, air-conditioning and other industrial purposes. Larger cement works have also used the slag for the production of portland cement. Slags containing phosphorus have been found useful for soil amelioration. In addition it has been used for the building of roads, manufacture of concrete and as rail-road ballast. In U. S. A., all these uses consume only 40% of the total production of slags (1938), the rest are evidently dumped near the works or thrown into the sea.

The slags of non-ferrous industries are used for similar purposes. Slag heaps of medieval period carry considerable amount of metals.

Slags carrying lead and zinc in appreciable quantity are now treated in specially designed furnaces where the metals are vaporised and recovered. It is surprising to note that slag heaps, found in Southern Spain and attributed to the smelting of copper ores by the Romans, are very low in copper content. It is believed that the Romans used considerable quantity of salt during the smelting operation, but kept the process secret. Subsequent generations, therefore, could not make use of this knowledge.

Pickle Liquor

Modern processes of galvanising, tinning, enamelling and electroplating demand thoroughly clean surfaces, so that the covering material will form a continuous and uniform protective coating.The special needs of these industries have given rise to modifications of rolling mill practice, requiring thorough cleaning of the surfaces of rolled goods. This cleaning or "Pickling" is generally done with sulphuric acid, though hydrochloric and other acids are used in special cases, particularly with alloy steels. The acid is repeatedly used until practically exhausted. Composition of pickle liquor varies to a great extent according to the practice adopted, but may be taken on an average to contain 1—4%free sulphuric acid and 15% ferrous sulphate. Quantity involved is very large; in U. S. A., it amounts to 500-800 mill. gallons per annum. The discharge of this huge quantity into the streams not only depletes the water of its oxygen content, but the acidity of the water constitutes a danger to navigating vessels and industrial equipments. The iron and steel industry have spent large sums of money in promoting research to find out suitable methods of its utilization. Those efforts have been further stimulated by the work of the Mellon Institute. Although great progress has been achieved and the problem seems well on the road to solution, all efforts of scientists have so far foundered against the hard rock of economy. The comparatively high cost of equipment required for treating large quantities of the corrosive material and lack of adequate markets for most of the byproducts are important factors which have baffled the scientists, although a large number of processes (13) have been developed in recent years. The most important of these methods aim at the recovery of ferrous sulphate (copperas) and iron oxide. A new use of chlorinated copperas as an efficient coagulant for sewage and industrial effluents promises to create a large demand for it.

Pulp and Paper Industry Wastes

Raw materials used in the production of pulp and paper generally contain only 50% of recoverable cellulosic materials, the rest consisting of lignin, carbohydrates and other organic substances have to be removed in the process of manufacture. In addition considerable amounts of valuable fibrous material are carried away by the large quantity of water used in paper mills. These waste materials are often discharged into rivers and become a serious source of pollution. Researches for the utilization of these waste materials have been financed liberally both by the industry and the state in western countries. Though many interesting products have been obtained, the market of these products is inadequate and hence recovery processes have not yet found general acceptance. Important results may however be expected in not too distant future.

The most important contribution in this field is the Howard process (21) which consists of fractional precipitation of waste sulphite liquor by treatment with lime. Three primary products are thus obtained; the first fraction, consisting of calcium sulphite, recovers valuable sulphur for reuse in the process, the second fraction is the basic salt of lignosulphuric acid and as sodium or magneseum salt, may be used for tanning leather, softening water or as dispersion agent. Considerable amount of vanillin is also made by alkaline hydrolysis. The third fraction, carrying carbohydrate and other organic matters, is discharged as effluent. Recently, one of the products of lignin utilization, ethyl vanillate, has been found to be a very efficient food preservative without any toxic effect in concentrations used on persons consuming it.

Fermentation of the waste sulphite liquor into alcohol has been practised in Germany and Scandinavia where the price of alcohol is high. This process, however, utilizes only a part of the carbohyrates, the other part, present as pentoses, being unfermentable. The culture of food yeast seems a more promising proposition as the yeast consumes both pentoses and hexoses during growth.

In certain plants magnesium bisulphite is used for the cooking process. In such cases, the waste liquor is concentrated to about 45% solid content, when it can be burnt in boilers, utilizing the fuel value of the organic matter and recovering magnesium oxide for re-use in the process. This process of utilization has not been found suitable for calcium bisulphite liquor. The waste black liquor' of the sulphate process may be similarly concentrated and burnt, recovering terpentine and dimethylsulphide from the gases and the alkali from the ash.

It is well know that large quantities of water used in the paper machine, carry away the fibre and other ingredients used in paper manufacture. These ingredients consist of sizing and colouring materials, fillers and adhesives, and the effluent is commonly known as 'white water'. Various pulp saving devices called 'save-alls' have been developed to recover the fibre and other solid ingredients. Amongst the processes used for this purpose are: (*a*) Seiving through fine mesh wire screens, (*b*) filtering through cloth or pulp and (*c*) sedimentation or flotation. The most outstanding discovery for this purpose is the development of closed system, in which all the materials are fully recovered with practically no loss (9). It is now regarded as unnecessary to separate the fibres and other ingredients from water. Modern recovery system recirculates the white water into the process without separation of components—thereby producing a closed system with practically no loss. Formerly the loss of fibre was as high as 15-20%; this loss was considerably lowered by the provision of "save-alls"; the introduction of the 'closed system' has lowered the fibre loss to below 1% with complete utilization of other ingredients.

Forest Wastes

Utilization of vast quantities of forest wastes and other cellulosic wastes is an important problem and for many years, researches were directed to evolve better methods for the utilization of inferior wood, saw dust, bagasse, straw and other fibrous materials. Distillation with the production of charcoal and various byproducts has only limited application. During the war, charcoal was converted into producer gas which was used as a substitute for petrol in the propulsion of motor vehicles. For this purpose 2.5 kg waste wood gave a gas equivalent to 1 liter of petrol. With the establishment of normal conditions, this practice has disappeared. In several countries, wood wastes have been hydrolysed to yield animal fodder and sugar. This sugar may be used for the manufacture of power alcohol and for the cultivation of yeast. This latter industry deserves special notice as it supplies vitamin-rich concentrated protein food. Cultivation of yeast also consumes both fermentable and non-fermentable sugars produced by wood hydrolysis.

Low grade cellulosic materials have been used for the manufacture of high class fibre board. The pulp obtained by cooking wood wastes is compressed at extremely high pressures with the addition of a binder, usually a synthetic resin. The hard board thus produced does not shrink, may be made waterproof and fireproof, and is used for door panels, flooring and the like. An important development is the manufacture of parts of prefabricated houses by incorporation of these fibrous materials with cement. Standard size building blocks made of rice hulls, saw dust and portland cement have been placed in the market. They are reported to withstand high pressure, are impervious to water, can be sawed and hold nail without difficulty.

DISPOSAL OF INDUSTRIAL WASTES

The above instances of waste utilization have been chosen rather arbitrarily and do not necessarily represent the most important ones. Numerous other instances could be cited but seem unncessary, as my object is not to give an exhaustive review but to draw attention to the importance of the utilization problem. Methods of disposal of industrial wastes are no less important. Stress has been laid on utilization processes, not merely because of their inherent importance for national economy, but mainly because such recovery processes are integral parts of operations to deprive waste materials of their obnoxious character. Unless recovery is effected, the materials will have to be discharged into the air or water, giving rise to serious pollution problems. Moreover, such utilization also meets a part, if not the whole of cost of disposal and frequently brings profit. It is unfortunate that mere humanitarian considerations often fail to induce industrial management to undertake elaborate and costly processes of disposal. The realisation that waste materials are responsible for extensive damages to industrial machinery focussed attention on the problem of their harmless disposal. But it was only when the evidence came, that recovery processes would not only cover a substantial part of the cost but might actually bring profit, that economic and humanitarian considerations combined to promote hygienic disposal of wastes. But profit or no profit, utilization or no utilization, these wastes must never be permitted to pollute the air we breathe and the water we drink.

Atmospheric Pollution

Abnormal concentration of any kind of matter—gaseous, solid or liquid —in the air at the ground level may be taken as an indication of pollution. Such pollution is usually caused by gases, vapours and suspensions of solid and liquid particles. Some of these materials are toxic, some offensive and some injurious to life and property. If the concentration of these materials fall below a certain level, they become harmless. It is only when the concentration rises above this limiting value, that their presence becomes a danger to society. It is therefore necessary to ascertain this limiting or threshold concentration for different gases, vapours and dusts, and to discharge them in the atmosphere in such a manner that their ground level concentration does not exceed the limiting figure. If they could be discharged into air streams which did not come to earth, the problem would be alleviated and for this reason high chimneys are an advantage. The subcommittee of the Electricity Commissioners in U.K. (1932) reported that "Emissions from chimneys having a height 2½ times that of surrounding buildings, plus where necessary, the additional height to compensate for the contour of the adjacent land, will discharge into air streams which can be depended upon not to come into contact with the earth under normal conditions" (22).

Meteorology can be of great help in locating the most effective air currents which do not normally come to earth and in suggesting most suitable site for a new plant and appropriate height of the chimney so that the contaminats may be discharged in the air current.

The mass rate of emission of offending gases from the chimney has been found to be of fundamental importance (16). The maximum permissible rate for such emissions has to be specified and its relation to ground level concentration found out. This relation has been mathematically deduced and is given by the following formula:

$$C_o = \frac{1.55 \times 10^3 M}{vh^2}$$

where C_o is the ground level concentration (mg per cu. meter) of the contaminant, located at a distance of 10 chimney heights, 'h' is the height of the chimney (meters), M the mass rate of emission (metric tons per day) and 'v' the wind velocity (meters per sec.) (17).

Gases: Of the various objectionable gases, the damage caused by sulphur dioxide is perhaps the most extensive. Its corroding property in the presence of moisture is well known. When inhaled, it irritates the mucous membranes in the throat and causes violent coughing; the effect on people suffering from respiratory troubles may be disastrous. It has also great injurious effect on vegetable life at concentrations above 1 p.p.m. Combustion of coals containing sulphur is responsible for its generation. Fortunately Indian coals, with the exception of Assam and a few other varieties, are poor in sulphur content. Methods for the removal of sulphur dioxide from smelter and flue gases have already been discussed and are, generally speaking, quite efficient. Scrubbing operations may bring down the sulphur dioxide content to as low as .5—.75 p.p.m. Where the scrubbing operation is not practicable, the gas is discharged at a safe height in an inoffensive manner.

Sulphuretted hydrogen is detectable by its characteristic odour even in the concentration of 0.34 p.p.m. It is highly toxic to animals. Organic sulphurous gases such as carbon dispulphide, mercaptans, alkyl sulphides are also toxic and obnoxious. They are usually removed by scrubbing and adsorption processes. If present in small amounts, a more effective way is to burn them into sulphur dioxide. Another toxic gas, carbon monoxide, owes its presence to inefficiency *i.e.,* to defective combustion or to leakages in the system. Modern industrial practice has almost completely eliminated this nuisance. Acid fumes, chlorine and other toxic gases have to be treated at the source, usually by the scrubbing process. Alkalies have often to be added in order to control pH and corrosion. In the case of sulphur trioxide, electrostatic separation is widely used.

Vapour:

Offensive vapours are sometimes generated in considerable amounts in the course of industrial operations such as distillation of petroleum, extraction by volatile solvents, and various other processes involving chemical reactions. Climatic conditions and inefficient operations aggravate this nuisance and enhance the risk of fire and explosions. The effect of continuous inhalation on operatives may be serious. Appropriate measures at the source are possibly the best means for checking these contaminants. Such measures differ according to the nature and concentration of the vapour. Proper ventilation, prevention of leakages, use of scrubbing and adsorption processes followed by subsequent recovery are the most effective methods in dealing with them. Where scrubbing or recovery processes are not practicable, the vapours are either burnt or the scrubbing liquor is discharged into river. In the latter case, the atmospheric pollutant is merely transferred to stream water.

Dust and Smoke:

Considerable amount of fine particles is discharged into the atmosphere from industrial operations such as the following:—

(*a*) Power generating plants, using high ash coal and discharging the same as fly ash.
(*b*) Smelting operations, carrying fine particles into the flues.
(*c*) Cement works, using finely ground materials in rotary furnaces.
(*d*) Vehicular traffic, generating dusts from roads.

The nuisance value of these dusts is well known. Soiling of clothes, dirtying the rooms and furniture are constant sources of irritation in larger towns. Greater incidence of lung diseases in cities and industrial areas shows that the effect of smoke and dust on human health cannot be ignored.

There are numerous devices for dealing with the industrial dust problem, of which the following may be specially mentioned:

(*i*) Electrical precipitation (Cottrell process),
(*ii*) Washing of gases (scrubbing and spraying)
(*iii*) Centrifugal precipitation,
(*iv*) Cloth filtration, settling chambers etc.

The electrical precipitation is the only system which gives uniformly good result with both corrosive and non-corrosive gases, but this process is a costly one and hence not acceptable to smaller industries. The wet washing systems have attained a high standard of efficiency but are corrosive in the presence of acidic gases. Dry types of dust collectors, such as the centrifugal system, have rather low performance when the discharge rate is high. Waste sulphite liquor, when concentrated or evaporated to dryness, has adhesive property and when dissolved in water and sprayed on roads, is reported to have given satisfactory results for the control of dusts.

The smoke problem (23, 18) is more difficult to deal with, specially when clouds of smoke emanate at a low level from numerous kitchen windows or brick kilns. An improved and generally acceptable device for the kindling of domestic coke is an urgent necessity in this country. Improved methods of combustion and high chimneys have effectively eliminated this nuisance in modern industrial furnaces.

Water Pollution

Rivers and streams are capable of immense good or evil according to the use or misuse we make of them. The purity of our domestic and industrial water is of vital importance. Our water ways must be safe for navigating vessels and harmless for aquatic life and agricultural use. Great care and judgment are necessary to keep the water reasonably pure. Organic matter, suspended particles, acids, alkalies and salts are the usual contaminants. The organic matter is perhaps the worst offender. It absorbs oxygen from the water and thus reduces the oxygen content. The rate of reduction of oxygen is generally greater than the rate of its increase by absorption from the air. When the oxygen content falls below 4 p.p.m., water becomes unfit for drinking and when it falls below 2 p.p.m., aquatic life is generally suffocated. The fall of oxygen content is also associated with the appearance of other offensive conditions such as colour, odour and taste. For these reasons biochemical oxygen demand (B. O. D.) is taken as a measure of pollution. Of the chemical methods, the chromic acid wet combustion method gives more reliable results than the oxygen consumption determined by the concentrated permanganate method (24).

The suspended matter gradually settles to the bottom and when organic in nature, ferments under anaerobic conditions prevailing at river beds and is often carried mechanically to the surface with the bubbles of gases evolved in the process. When the particles are finely dispersed, they cause opalescence and are sometimes responsible for the clogging of filter beds. In such cases, chemical coagulation is often resorted to. Acid water causes corrosion and is dangerous to navigating vessels and industrial equipments. Acids also suppress bacterial growth and thus retard the 'self-purification' process. Alkalies and salts cause colour and taste, and are toxic to aquatic and plant life. Phenols are also toxic and responsible for taste in drinking water, which aggravates with chlorination due to the formation of p-chlorophenol.

The worst contaminants are sewage and industrial effluents. The B. O. D. of industrial effluents in certain areas may even be higher than the B. O. D. of the sewage of a small town. Distillation residues in fermentation industry, jute retting effluents of paper and pulp, tanning, soap, chemical and pharmaceutical industries are made up largely of organic matter and suspended particles. Coal mines, steel and associated industries and petroleum industry discharge considerable quantities of acids and salts. The character and composition of the effluents of each industry differ from the other and the alleviating measures, which must be based on the quantitative and qualitative composition of each effluent, must necessarily be different. Frequently, the discharge from two sections of the same industry differs considerably in character and concentration. Principles of chemistry and chemical engineering play an increasingly inportant role in devising satisfactory measures of control.

Rapid Progress of Control Measures:

The capacity of a stream for 'self-purification' depends on the volume and rate of flow of its water, which vary greatly according to season and contour of the locality. The self-purification capacity is also related to the character and quantity of effluents discharged into the stream and should be studied with special reference to these factors. One of the cheapest and most efficient methods of treatment is to mix industrial effluents of organic nature, after proper dilution and adjustment of pH with sewage and subject the mixture to biological treatment. The effluents of anaerobic fermentation have high B. O. D., colour and odour, due obviously to the presence of organic matter in dissolved state. These effluents must therefore be stabilised by further 'aerobic' fermentation in trickle filters or activated sludge tanks.

The chemical and physical methods of control are based on the properties of various discharges. These methods consist of separation of effluents according to concentration and character, adjustment of pH, sedimentation, aeration, coagulation, filtration and chlorination. Lime and sulphuric acid are commonly used for adjustment of acidity or alkalinity ; ponding or storage tanks for sedimentation; ferric sulphate, alum and chlorinated copperas for coagulation and sand and other porous beds for filtration.

Methods of control are constantly undergoing modification and improvement. The scrubbing methods of removing objectionable ingredients have been partly replaced by the use of adsorbents, usually activated carbon. Introduction of ion exchange materials, capable of quick regeneration by the simple process of washing, has brought simplification and economy in water softening processes. The recent discovery of amberlite resins, some of which have ion exchange properties under a wide range of pH and dilution, has opened up new possibilities not only for water refining but also for recovery of metallic elements from various industrial effluents. Introduction of the flotation method for the recovery of many useful fibrous and other materials from suspensions constitutes a substantial improvement over older methods and combines antipollution measures with economic recovery. Reference has already been made to the development of the 'closed system' in paper and other industries, which is an excellent example of the combination of full recovery of waste materials with almost complete prevention of pollution. The most satisfactory methods are those which attack the contaminants at the source, recovering them for useful purposes where-ever possible, or destroying them where-ever necessary.

THE NEED FOR A NATIONAL PROGRAMME

Standing on the threshold of industrialisation, it is time for us to reflect on the raw material position on the one hand and possible evil consequences of industrialisation on the other. Only then shall we be able to devise and take appropriate measures for remedy. Our shortage of sulphur and some essential minerals is well known. We do not yet produce some important chemicals which we badly need. At least some of these materials can be recovered in substantial amounts from industrial wastes. We are throwing away some valuable potential fertilisers which we urgently need to increase our food production. We can, at least partly, meet our shortage of building materials by utilising various waste products which we do not use, or at best, use only as fuels. Are we entitled to pollute the air and water, and thus endanger public health and happiness? Can we afford to be indolent? The answer to these questions is obvious. The main difficulty is,—we do not know what is to be done and how to do it. Fortunately, experience of the West can give us some clue to these problems.

The first essential pre-requisite is knowledge. At present we lack knowledge of the character and quantity of wastes discharged individually and collectively by different industries. We do not know the methods of control and reclamation, and lack fundamental data upon which these methods are to be based. An expert committee must survey which of these methods, under conditions prevailing in this country, may be remunerative, which may 'break even', and which may be suitable only for the abatement of pollution. The capacity of streams for dilution and self-purification in different seasons has to be investigated. Samples of water and air, collected at different distances from the source of contamination, have to be analysed and the results co-ordinated. We do not know the minimum permissible limit of different contaminants and the setting up of an authoritative body whose opinion in this matter may be relied upon is an urgent necessity.

In Europe and America, the necessary information is collected by high level commissions, committees and research organisations set up by the State and the Industry. In England, the Royal Commission on River Pollution, the Royal Commission on Sewage Disposal and the Standing Committee on River Pollution (25) have exhaustively reviewed the position and the Research Institute on River Pollution is doing valuable work in collecting fundamental data,—an essential prerequisite for corrective measures. In U.S.A. the federal government, the states and the industries are each tackling the problem in their own spheres. The Special Advisory Committee on Water Pollution of the National Resources Committee surveyed in detail the existing position in U.S.A. (26). Under the auspices of the Public Health Department, a research organisation known as the 'Water and Sanitary Investigation Station' has been set up at Cincinati. In addition, the famous Mellon Institute, the M.I.T. Sanitary Laboratory and the University of North Carolina are carrying on fundamental investigations on utilization and pollution problems. In 1946, the American Public Health Association set up a Committee on Sewage Disposal. Industrial organisations are also contributing liberally to the solution of the problem. Mention any be made of the researches directed to the waste utilisation and disposal problems carried out under the auspices of the Iron and Steel Industries, Mineral Oil Industry (Philadelphia), Textile Foundation (Princeton) and Paper and Pulp Industry (Appleton). The co-operative efforts of the Paper and pulp Industries have led to the establishment of the National Council for Stream Improvement which has been functioning since 1944.

The second important requirement is the settling up of an administrative authority vested with adequate power to promote and control waste treatment. The Government of the country, responsible for its industrial policy, cannot dissociate itself from the consequences of the policy. Public health and welfare are vitally involved. The task cannot be left to individual initiative. Considering the nature and magnitude of the problem, effective action has to be based on close co-operation of the Centre, Provinces, Municipalities and Industries. A programme of work on national lines can be drawn up only by the combined efforts of men of knowledge in widely different fields—scientists, technicians, administrators and financiers. Would an existing or reorganised department of the Government be competent to undertake the task with reasonable chance of success? Or would it be more desirable to set up a separate organisation for the purpose similar to the Allegheny County Sanitary Authority in U.S.A.? What would be the constitution, scope and functions of such an organisation? How should a government department be reorganised, if it is decided in favour of such a course? How are the researches and control measures to be financed?

Only a National Committee, similar to the Royal Commission in England and National Resources Committee in U.S.A. can find satisfactory answers to these questions. The constitution of a National Committee in this country must not be postponed indefinitely. We have a duty to society. We can shirk taking action for some years, but we cannot shirk the consequences.

REFERENCES.

1. Baehr—*Chem. Fab.*, 11, 10-20 (1938).
2. Ungewitter—"*Science & Salvage*" (Trans. by Fermey & Haim, 1944).
3. Gollmar—*Ind. Eng. Chem.*, *39*, 596-601 (1947).
4. Leithe—*Bren-stoff. Chem.*, *22*, 49-57 (1941).
5. Chowdhury & Dutta—*J. Ind. Chem. Soc.*, *20*, 253-60 (1943).
6. Eldridge—"*Ind. Waste Treatment Practice*" (1942).
7. Powell—*Ind. Eng. Chem*, *31*, 789-96 (1939) Gollmar, *ibid*, *26*, 130-32, (1934).
8. Lorenzen—*Chem. Feb.* *12*, 6-23 (1939), Bahr, *ibid*, *11*, 283-92 (1938).
9. Warrick—*Ind. Eng. Chem.*, *39*, 670-76 (1947).
10. Candall—*Chem. Met. Eng.*, *34*, 143-47 (1927).
11. Rosener—*Chem. Fab.* *10*, 101-6 (1937).
12. Chowdhury & Hossain—*J. Ind. Chem. Soc.*, *8*, 81-93 (1945), Sen & Das-Gupta *ibid*, *11*, 71-76 (1948).
13. Hodge, *Ind. Eng. Chem.*, *31*, 1364-79 (1939), Hoak, *ibid*, *39*, 614-18, (1947).
14. Das-Gupta & Das-Gupta—*J. Ind. Chem. Soc.*, (*Ind. News*), *4*, 16-20, (1941); Mehta & Purmahamed—*ibid*, *8*, 9-14, (1945).
15. Tripp., *J. S. C. I.*,—*58T*, 1102-4 (1939).
16. Bonsanquet & Pearson—*Trans. Farad. Soc.* *32*, 1249-64, (1936).
17. Hemeon & Hatch—*Ind. Eng. Chem.*, *39*, 570, (1947).
18. Nonhebel—*Trans. Farad. Soc.*, *32* 1291, (1936), Owens, *ibid*, *32*, 1234, (1936).
19. Siecke—*Chem. Fab.*, *8*, 415, (1935).
20. Mukherjee & Dutta—*Science & Culture*, *14*, 538, (1949); *14*, 213, (1948).
21. Howard—*Ind. Eng. Chem.*, *22*, 614-17 (1934).
22. Monkhouse—*Chem. & Ind.*, *58*, 596-600 (1939).
23. Gray & Peterson—"*Smoke*", Arnold, (1932).
24. "*Standard methods of Exam of Water and Sewage*"—publ. jointly by Amer. Public Health and Water Works Assns. New York (1946).
25. (*i*) Royal Commission on River Pollution, 1st. Comm.—*3 rpts.* (1865-68), 2nd Comm. *5 rpts.* (1863-74. London, H. M. Stationery office.
    (*ii*) Royal Comm. on Sewage Disposal—*9 rpts*, (1901-15). London.
    (*iii*) Standing Committee on River Pollution, (Br. Ministry of Agri. & Fisheries), *4 rpts.* (1921-27), London, H. M. Stationary office.
26. National Resources Committee—*3rd Rpt.* of Special Advisory Committee on Water Pollution, Washington D.C. (1939).

37th INDIAN SCIENCE CONGRESS, POONA, 1950

SECTION OF GEOLOGY AND GEOGRAPHY

PRESIDENT: J. COATES A.R.S.M. F.G.S. F.N.I. F.Inst.Pet.

Presidential Address.

THE PROGRESS OF OIL PROSPECTING IN THE INDIAN UNION

INTRODUCTION

It is a very special occasion in one's professional life to be invited to be the President of a Section in the Indian Science Congress, and I must thank you very much for the great honour you have done me. I feel this the more deeply because a geologist engaged in the economic applications of the science is very conscious of his shortcomings compared with the knowledge of his colleagues in the Academic sphere and the Government Geological Survey.

2. Before I go further, I am sure that you would wish me to make a brief reference to the passing this year of two men of science who were specially connected with this Section. In April there came the tragic and unexpected loss of Professor Birbal Sahni, who although best known as a famous Botanist, was President of this Section in 1926, and was particularly interested in the geological bearing of his researches, and a personal friend of many of the geologists here today. Later in the year came the news of the passing of Sir Edwin Pascoe, Director of the Geological Survey of India from 1921 to 1932, and still engaged on a professional work of great importance to us all. I would ask you to recall with gratitude the work which these men have done for the furtherance of science in India, and to stand for a few moments in silence in their honour.

3. Now that so much effort is being devoted to planning and carrying out great schemes which represent the application of science to practical affairs, no apology is probably needed for selecting, as the subject of this Address, a topic which is not purely of academic interest but in which the theoretical and the practical are interwoven quite inextricably. It is no longer regarded as any debasement of science to turn it to the affairs of everyday life; rather does one thus obtain a widened field of investigation, and the stimulus of having to test one's hypotheses by experiments on a grand scale.

4. In giving this account of the progress of prospecting for Petroleum in the Indian Union, I want to combine two main objectives: firstly, to present a general historical record (of which no convenient summary has recently been made), and secondly, to use this story to illustrate the development of oil-finding technique and the progressive application of scientific methods in what was initially an almost wholly empirical art.

5. Oil Prospecting in India is a very suitable topic for such a combination, because the drilling of wells for oil on the modern basis started in India very soon indeed after its first beginning in the U. S. A. The date of the Drake well in Pennsylvania, 1859, is usually taken as the beginning of the modern oil industry ; and by 1866 there were wells drilling for oil in Assam. So the story of oil prospecting in India will be found to represent all stages in the development of the subject.

HISTORICAL SEQUENCE OF PROSPECTING

6. When Oil Prospecting started in the Indian Union it was so early in the development of the industry that prospecting was purely empirical and no reasoned hypotheses had been developed. The prospector looked round for the evidence of surface seepages of petroleum, set up his outfit on the nearest convenient spot, and went on drilling until it became mechanically impossible to drill any deeper, unless he struck oil first.

7. This procedure was (in spite of many failures) giving quite encouraging results in America, and the general outlook in India seemed reasonably comparable. There were belts of ground in which oil seepages were plentiful, and they lay geographically between the similar oil seepages of the Punjab-Baluchistan area and the hand-dug well oilfield area of Burma. In 1866 and 1867 therefore some attempts were made to drill for oil in Assam near the seepages : three wells were put down at Jaipur and three at Makum. They were what we should now call very shallow, less than 200 ft., but the Drake well in Pennsylvania obtained quite good production at only 69 ft.

8. These first wells were partially successful in that they found some oil, but not enough to arouse any enthusiasm for continuing. Nevertheless, after a few years (1888 to 1893) another firm sank several more wells at Makum—getting enough oil to warrant putting up a small refinery—and started drilling also at Digboi. By this time drilling technique had improved so that several of the wells were over 500 ft. and one even passed 1000 ft., and this gave a better chance of finding an oilsand somewhere, and of obtaining enough oil to make the venture remunerative.

9. As we now know, operations on these lines are very likely to find a little oil but relatively unlikely to find a great deal ; and they have the great drawback that any degree of failure leads to no suggestion about what might be done to improve the position—except to drill a bit deeper, or to try again somewhere else. These Assam Wells were fairly true to type.

10. The reasons for this are easy to understand. The surface seepages owe their existence to the outcropping of an oilsand or to the proximity of a fault which forms a channel for the escape of oil from a lower level. Unless there is some sealed-in reservoir present, such as a porous bed capped by an impermeable clay (and this would probably come at some rather deeper level), there is nothing to cause any concentration of the oil : except perhaps for the partial sealing effect of the waxing-up of the exposed surface by the evaporation of the escaping oil.

11. As it happens, from what we now know, the Makum sands then within reach all outcrop at the surface, and the wells had no chance of finding substantially better conditions below. At Digboi anticlinal structure does exist, but these early wells were unlikely to go deep enough to get the full benefit of it.

12. At this stage the results in the rest of the subcontinent had been discouraging ; the wells drilled by Government at Khattan in Baluchistan, and elsewhere in that region, had proved to be financial failures in spite of the initial encouragement of finding some oil ; and the Assam operators probably felt that a certain amount of caution would be wise. There followed therefore quite a long period during which nothing much was done in the way of looking for new fields, effort being concentrated on mild but persistent development of the areas where oil had actually been found.

13. By this time operators all over the world—and particularly of course in the U. S. A.—had been trying to better the results of their early prospecting and to deduce how new fields might be found through knowledge of what geological conditions give rise to oil accumulations. Two broad generalisations were made : (*a*) that oil tended to occur, in each region, in rocks of some particular geological horizon, and (*b*) that accumulation occurred in anticlines. These principles brought in the geologist as an essential specialist in oil prospecting, and opened up new possibilities of finding oil-fields even where no surface indications of oil existed.

14. So in India systematic geological mapping for oil exploration was instituted (from about 1908 onwards), and as the Geological survey of India had barely touched the Assam Tertiaries at that stage (except for reconnaissance) the work was left almost entirely to the Oil Companies. There was a tremendous area to cover, including of course in those days the region now in Pakistan, as well as the whole Tertiary belt from Assam down to Arakan ; the latter presented a peculiarly difficult problem because of the relative absence of fossils and the variable lithology of the rocks.

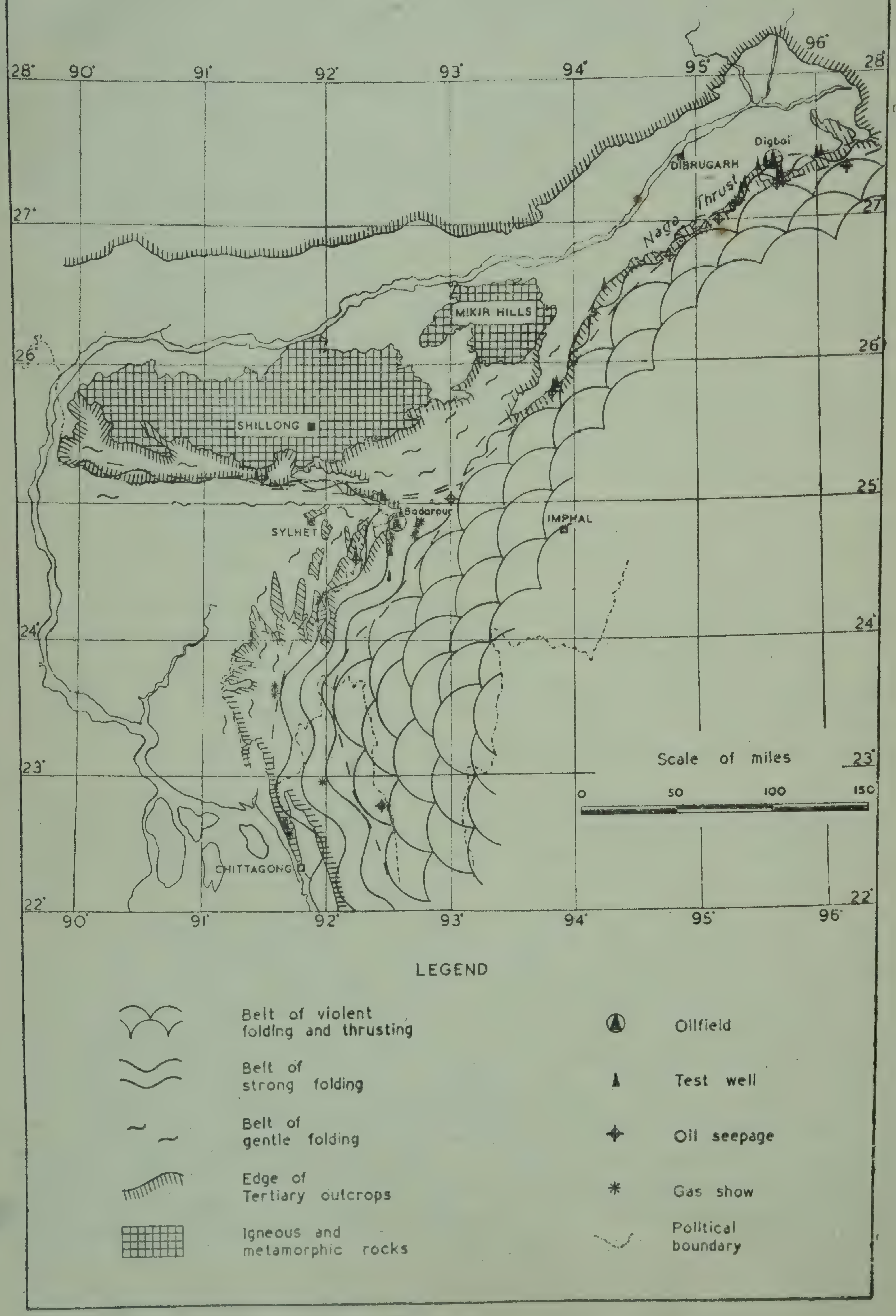
15. Interest was sustained in India by the continuance of production at Digboi and by the opening of the Badarpur oilfield which also conformed to current specifications of oilfield types by being anticlinal in structure. This field had actually been indicated in 1901 by a hand-dug well situated near an oil seepage and was taken up in 1910 by a syndicate ; in 1915 they passed it on to a company already producing oil in Burma, who pushed ahead with the development of Badarpur.

16. The success of these centres provided a stimulus for further effort, especially as a temporary diversion of attention to the Punjab (due to the proving of the Khaur field in 1914) was relaxed in consequence of various failures in other test wells in the Punjab and Mekran.

17. The picture that emerged from the systematic mapping of the eastern areas was roughly as shown in Plate 1. The Tertiary rocks, in which all the known oilshows occur, form a long belt in and at the edges of the chain of hills between Burma on the south and Assam, Sylhet and Chittagong on the north and west. North and west of the exposed rocks are plains of alluvium, through which the metamorphic rocks of the Shillong plateau protrude. The south-eastern parts of this Tertiary belt, running in and near the high mountain ranges, are very severely folded and thrust-faulted ; towards the north-west the intensity of the folding diminishes, until along the borders of Sylhet the folding is very gentle indeed and only beds of high horizon are exposed. In Upper Assam one sees very little of this gentle folding, the alluvium coming usually right up to the belt of moderately intense folding.

Plate I

THE TERTIARY BELT OF EASTERN INDIA


28°
90°
91°
92°
93°
94°
95°
96°
27°
26°
25°
24°
23°
22°
DIBRUGARH
Digboi
Naga Thrust
MIKIR HILLS
SHILLONG
Badarpur
SYLHET
IMPHAL
CHITTAGONG
Scale of miles
0
50
100
150
LEGEND
Belt of violent folding and thrusting
Belt of strong folding
Belt of gentle folding
Edge of Tertiary outcrops
Igneous and metamorphic rocks
Oilfield
Test well
Oil seepage
Gas show
Political boundary

18. The oil indications follow a roughly similar graduated pattern, though not exactly parallel to the structural trends. In the belt of faulting and intense folding (and sometimes in the zone of merely strong folding) there are surface seepages of oil in fair plenty, but towards the belt of gentle folding the oil seepages cease and are replaced by shows of gas without any accompanying oil.

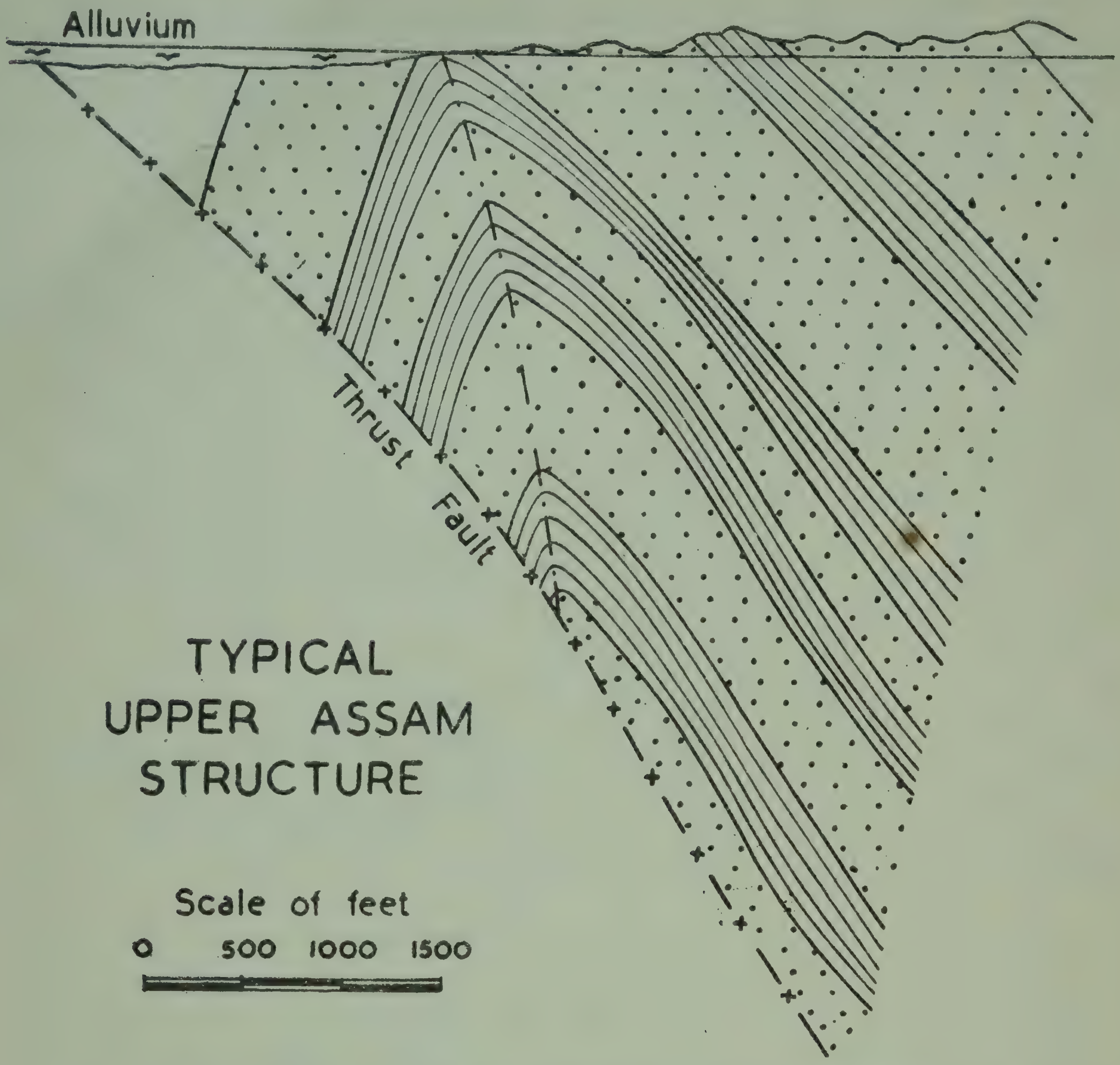
19. From the oil prospecting point of view this situation presents the difficulty of opposing factors. On the one extreme we have the assurance of the general existence of oil but the absence of suitable structures to contain it ; and on the other side we have apparently suitable structures (large and not severely faulted) but no assurance that oil-forming conditions have extended within their reach : they might be quite barren, or they might contain gas without any oil. And, further, these gentle structures are also less eroded, so that an increased thickness of rocks remains to be drilled through to reach any given horizon, and there is the added uncertainty of intervening unconformities masking the underground structure. The selection of a test-well site has therefore to balance these conflicting considerations.

20. On this basis, a number of structures in the intermediate belt were taken in hand for testing, between about 1918 and 1925 ; some in Upper Assam and some in the Surma Valley. In no case, unfortunately, was conclusive success attained, though in several of them enough doubt remained to make it worth giving them further consideration. It is instructive to analyse the reasons for this.

21. In Upper Assam the alluvium comes close up to the edge of the belt of strong folding and faulting (instead of leaving a strip of gentle folds as in the Surma Valley), and although we have the evidence of Digboi Field to show that accumulation is possible in one of these marginal overthrust folds, it is only in this frontal line (and perhaps the next line behind it) that the intensity of thrusting is likely to be low enough to leave sealed reservoirs.

22. A section through part of the Digboi field typifies the conditions in these frontal folds. The thrust fault which underlies the structure has quite a high hade, so that although near the surface there is an anticlinal fold, at some distance below the surface the thrust cuts across the axis of the fold and leaves only a monoclinal flank abutting against the fault, or even runs parallel to the flank dips so that the downward extension of the structure is quite definitely limited; below the fault are beds of very high horizon, with no indication of structure suitable for oil accumulation even if one were to drill very deep.

23. Now in different parts of these folds running parallel to the edge of the alluvium, erosion has reached various levels and the thrust comes in at different structural positions. When no anticlinal reversal remains at the level of the potential oilsands, it has been proved (as one would have suspected) that no significant oil accumulation takes place. There are several places where there is quite definite anticlinal reversal at the surface before the fault is reached, and at the beginning of testing high hopes were, naturally enough, entertained ; but in one area after another it turned out that the thrust fault had an unexpectedly high hade, so that the structure proved barren of oil on test.



24. In the Surma Valley the conditions—and the sequence of operations—were different. A variety of structures were selected for testing, all fairly near the oil indications and within range of the positive evidence of the Badapur oilfield. Wells drilled were of the order of 3000 ft. deep (which was quite a successful achievement for those days), a depth which was expected to bring them to the horizon of the oilsands of the Badarpur field. Here again, however, there was a disappointing absence of positive success in the way of proof of the existence of a potential oilfield.

25. Quite a number of factors were involved in the lack of success in these wells. For one thing, although the drilling was actually carried to about the depths intended, very considerable (and abnormal) difficulties were encountered in the way of water-sands of unusually high pressure, with gas, and shale formations which crumbled and squeezed in to the hole. This is not the place for discussing problems of this type, and it will be enough to mention that the overcoming of them, then and later, led to many very interesting developments in drilling technique, some of which represented pioneer work in scientific applications in the industry.

26. Another thing found was that the Badarpur oilsand horizon was not, after all, encountered at the expected depths, so that the correlations needed adjustment. The economic need for solving this problem, and the absence of the more usual guides of macro-fossils or distinctive lithology, led to a great deal of intensive work in the application of Heavy Mineral

Analysis—then virtually in its infancy—which has since proved of great practical value. More recently, micro-foraminiferal investigation and micro-palaeobotanical research have been directed towards the same problem.

27. A further feature discovered was that the underground structures disclosed by the test-wells—according to the dips found in the cores and correlations by lithology—were not at all what had been expected from surface data. This led to a study of the technique of drawing geological sections when beds do not maintain constant thickness, amplifying the earlier work done in Burma and elsewhere by Busk and others, and this technique (summarised in an earlier paper before the Indian Science Congress) does not appear to have been applied in other countries. There has resulted a considerable improvement in the forecasting of details of depths to key beds, and of the axial hade of folds ; and it has been supplemented by the practice of drilling preliminary core holes (often on quite an intensive scale) to get a clue to the major features of the underground structure.

28. In Upper Assam the failure of the various test-wells was to a large extent conclusive discouragement, in the conditions then obtaining as regards technique of drilling and knowledge of prospecting possibilities, and effort towards the discovery of new oil resources was mainly concentrated in the direction which had the best hope of success—i.e. the extension of the Digboi oilfield. Here quite a striking series of successes have been obtained from time to time, interspersed with a corresponding set of disappointments, and the field was gradually extended to its present known limits, which are fairly sharply defined by structural factors in regard to depth and width across the structure, but which along the strike of the fold have been enormously extended (with resumption of production after intervening barren patches) according to the interplay between structure and the texture of the reservoir beds. This activity, although not included in the list of test wells in Appendix A, was essentially similar in nature and has continued up to the present day.

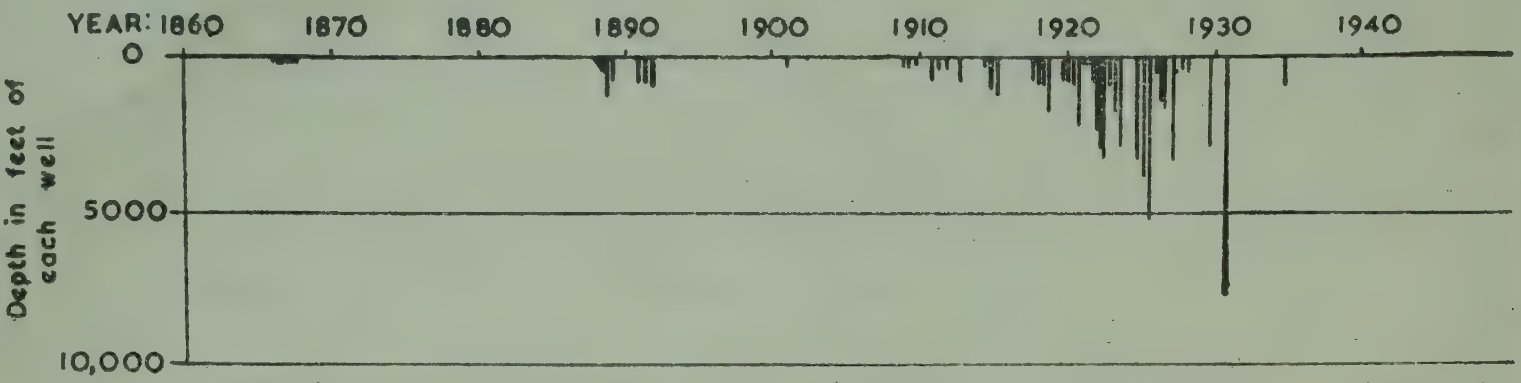
29. In the Surma Valley, during the corresponding period, it was felt that in spite of the failure of the earlier test wells there were still prospects if the difficulties involved could be overcome by sufficient thought and effort. Accordingly the most apparently promising of these areas—Masimpur, which is a structure of relatively large size—was selected for intensive effort, in the hope that the experience and success there gained could be applied to the other areas whose prospects were linked with it. For this reason there has been a continuous sequence of test wells in this same area (No. 7 is the next one planned) and a campaign of core-drilling involving more than 100 separate bore-holes (some over 5000 ft. deep) ; but although operations there have exhausted over 2 crores of rupees so far, and the last well reached 7685 ft, each difficulty surmounted has disclosed other problems ahead, and the area cannot yet be considered finally tested.

30. Independently of the connected sequence of operations recorded briefly above, an attempt was made by a different company from abroad to test the oil possibilities of this part of the world, which had previously been left mainly to the indigenous oil companies. A few wells were drilled in the Upper Assam belt, but they also had a similar lack of success.

31. The historical sequence of prospecting wells in the Indian Union (including their depths) is recorded in Appendix A and shown diagrammatically in Text-Fig.2. It shows how improvements in drilling technique have allowed wells to be carried deeper and deeper, thus extending the scope for testing.

Text Figure 2

DIAGRAM TO SHOW SEQUENCE OF THE MAIN PROSPECTING WELLS IN THE INDIAN UNION.



Each stroke represents an individual well according to date of starting and total depth reached.

32. During the recent war period, all prospecting effort had to be shut down at Government request in order to conserve material for work which was likely to yield immediate supplies of oil for the refinery, and it has only quite recently been possible to restore the supplies and organisation for resuming prospecting effort. At the present time the position changes from week to week, through a variety of factors ; apart from the test-wells for extending the Digboi field (which have shown a fairly definite termination of the field to the south-west, though there have been some recent quite striking successes in additions to the north-east), a test-well has been drilling at Tiru Hills in the Assam Valley and has (during the writing of this Address) proved one more example, unfortunately, of a prospect whose potentialities were cancelled out mainly by unpredictably unfavourable underground structure ; this was one of the few anticlinal structures still untested in the Assam Valley region. In the south-western part of the Tertiary belt, it has not yet been possible to make a final decision on programmes, but plans are in hand for drilling at Masimpur and (in Tripura) at Rokhia should circumstances allow.

33. A little before the war, it was decided that the technique of geophysical survey (which had been employed from time to time on local problems) was now sufficiently advanced to allow of a practical attempt to determine the prospects under the wide plains of alluvium. Surveys were started intensively over the whole sub-continent, then undivided ; the only portion appropriate for this work in the Indian Union was in the Upper Assam Valley, neglecting for the moment some portions at the western edge of the Indian Union, which will be referred to later.

34. The Assam Valley alluvium offers three main problems in this connection. Firstly, is there a sufficient thickness of sediments above the basement to give scope for prospects ; secondly, do anticlinal structures exist below the alluvium ; and thirdly, does the oil-bearing belt extend north of the Naga Thrust which runs along the edge of the exposed rocks? Of the data obtained on the first two points it would be premature to speak here ; the third point, on which Geophysics can give no answer (and only actual drilling can solve) might possibly prove to be of overwhelming importance, for so far no oilshows have been observed in rocks to the north of the Naga Thrust, and it is not impossible that they are different in facies from the oil-bearing rocks to the south.

FUTURE POSSIBILITIES

35. The prudent scientist who is anxious to preserve a reputation for soundness may be careful to confine his expressions of opinion to conclusions derived from demonstrable facts. The economic geologist, however, and particularly the oil geologist, spends much of his life in making forecasts about what will be discovered in the future, in the cheerful expectation of being proved wrong quite frequently ; it is, in fact, his continual professional duty to give opinions on insufficient evidence, and for him it is a far worse disgrace to fail to make some sort of forecast when requested than it would be to make an estimate and then be proved wrong, even though very large sums of money may be risked on the strength of his opinions. Following in these habits, I may perhaps be permitted to peer into the future and speculate about the further possibilities of oil resources in India, and the techniques that will be used to discover them.

36. For this purpose we may use a generalised Geological map (see Plate II) of the country. Firstly, we may exclude from discussion all that large part of the country which is composed of igneous or metamorphic rocks. That leaves us with three categories of sedimentary series ; the Tertiary beds, the pre-Tertiary rocks (e.g. Gondwanas etc.) and the oldest Palaeozoic and pre-Cambrian sediments.

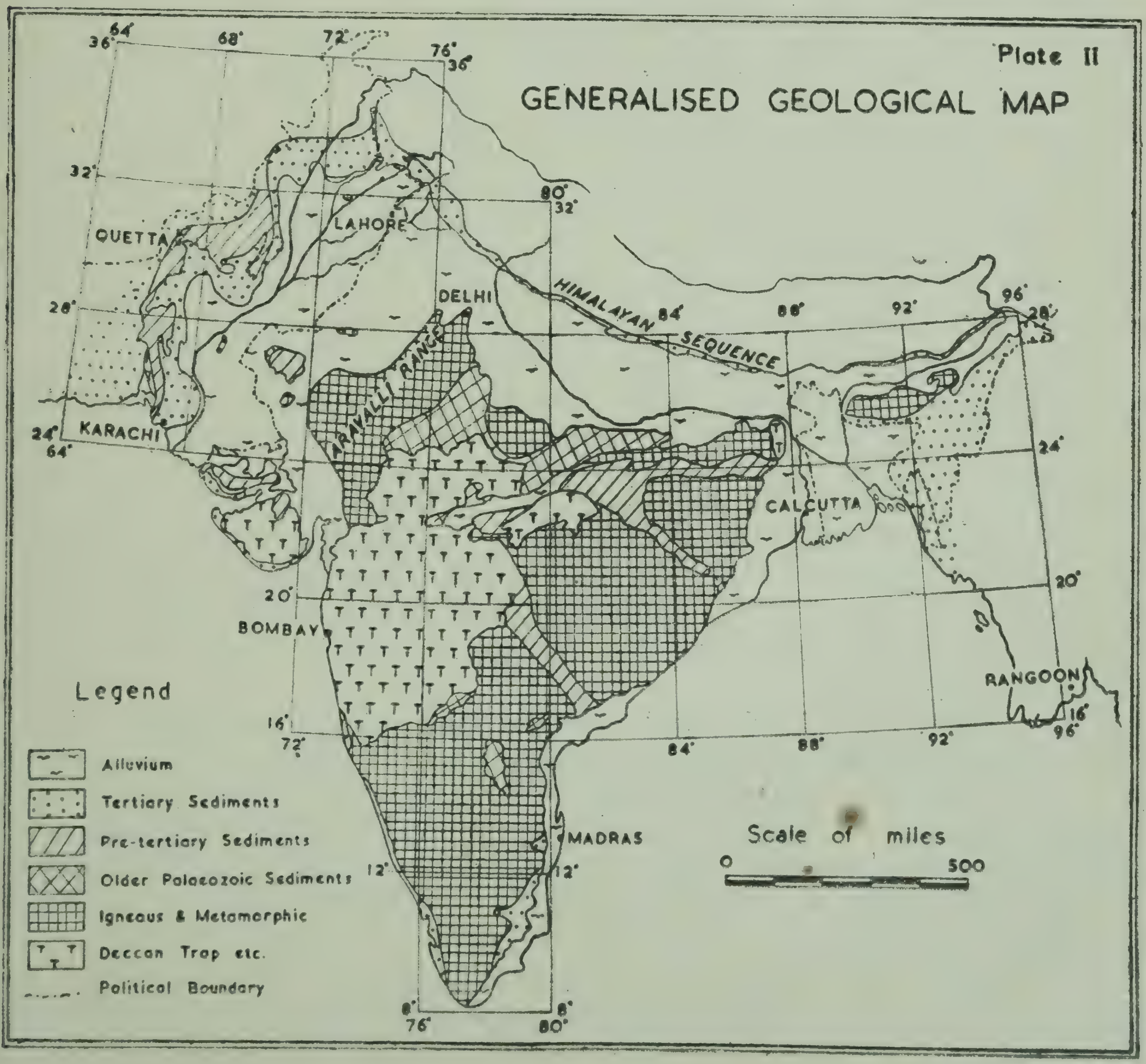


Plate II

GENERALISED GEOLOGICAL MAP

QUETTA
LAHORE
DELHI
ARAVALLI RANGE
HIMALAYAN SEQUENCE
KARACHI
CALCUTTA
BOMBAY
RANGOON
MADRAS
36°
64°
68°
72°
76°
80°
84°
88°
92°
96°
32°
28°
24°
20°
16°
12°
8°
Legend
Alluvium
Tertiary Sediments
Pre-tertiary Sediments
Older Palaeozoic Sediments
Igneous & Metamorphic
Deccan Trap etc.
Political Boundary
Scale of miles
0
500

37. In the Tertiaries, we have already discussed the Assam oil belt and need not refer further. The remaining Tertiaries are presumably the next best group of potential oil rocks ; particularly the belt of Tertiaries running along under the Himalayas, of which the section nearest to the Punjab oil region would appear the most promising. The reasons for considering this region relatively unpromising for practical purposes are mainly : firstly, that it is intensively folded and faulted, so that the chances are small of finding a reasonably-sized structure sufficiently intact to hold oil ; and secondly, that although there are shows of gas in places there is no direct evidence of oil-forming conditions, and it may quite well be that there has been a regional development of gas without any liquid hydrocarbons.

38. There are a few other occurrences of Tertiary beds in the Indian Union, for example those fringing the Peninsular. Of these it may be said in general that, being narrow and minor developments bordering a mass that has remained relatively stable through long periods of geological time, they seem unlikely to have provided the type of environment which would give oil-forming conditions. There are Tertiaries again round Cutch, and Eocene rocks occur in patches through the alluvium of Jaisalmer ; but on the whole these beds seem to be too freely exposed, and to be too near the edge of their area of deposition to offer much promise.

39. Apart, however, from the Tertiary sediments in which all the known oilshows of India occur, we must allow for the fact that, speaking in quite general terms, sediments of any age at all, to the very oldest in which any forms of life existed, might have had a chance to develope oil-forming conditions and retain their oil if they have escaped later metamorphosis, or violent tectonic disturbance, or erosion.

40. It must be considered that the Gondwanas on the eastern side of the Peninsular were laid down in an environment suitable rather for coal formation ; and, especially in the absence of any evidence of petroleum in any of the widespread localities where they have been examined, it seems most probable that they missed developing oil-forming conditions, at least in any developments still preserved from subsequent erosion.

41. On the Cutch and Jaisalmer side we have Jurassic sediments ; but these seem on the whole to be a shallow-water coastal facies, probably too well aerated for the preservation of potential oil-forming material. There are, of course, the well-known gas occurrences of Baroda—whether their origin is Recent or Tertiary or older—which have been found from time to time during shallow drilling (mainly for water, and not therefore discussed above) from 1911 onwards ; but these have shown no signs of oil, and all the knowledge we have of the local structural and stratigraphic features seems to be against the expectation of any accumulations of oil of any significant size.

42. Then as regards such of the still older sediments as are unmetamorphosed, the main initial consideration is that for oil to be preserved to this day (if ever formed) over such a long period of time would require somewhat unusual conditions of freedom from tectonic disturbances combined with protection from erosion or near-surface exposure. So far there has not been any reason to explore such possibilities seriously, but on general grounds the prospects appear to be fairly remote.

43. Besides the regions discussed already, we have still to allow for the areas whose geology is hidden from us, by the Alluvium or by the Deccan Trap. The Upper Assam alluvial area was discussed earlier ; but over the

remainder of the alluvial belt, as the geological map will show, the prospects are mainly those of the extension below the alluvium of pre-Tertiary rocks whose prospects seem poor or negligible. The least unfavourable region would seem to be to the west and north-west of Delhi; but the basement of igneous and metamorphosed rocks (such as appear at intervals as far away as Sarghoda near the Salt Range) must lie fairly near surface, without giving room for any thick development of sediments; and in principle the prospects must be presumed to be inferior to those across the border in Bahawalpur and West Punjab, where it is now known that the very extensive geophysical surveys have given discouraging results.

44. As regards the area beneath the Deccan Trap, we cannot say that it offers no potentialities, but looking for oil would be excessively speculative. There is no apparent reason why the Gondwanas (or any other sedimentary series) might not have an oil-bearing development somewhere in the trap-covered area: but we have no special reasons for expecting this to occur in any particular region, still less in any one closely defined locality. It would obviously present a very formidable (and perhaps insuperable) geophysical problem to deduce the structure and stratigraphy beneath the Trap, and when one considers that even if structure and stratigraphy could be revealed there would still not be any means of deducing the presence of oil (of whose existence in any such locality there is at present no evidence at all) then the whole prospect becomes so speculative as to be practically unattractive; the chances of failure are already sufficiently high even in prospecting apparently favourable areas.

45. Thus it seems unlikely that oil resources will be discovered in any useful quantity outside the eastern Tertiary belt which is still being examined. Except, however, in the case of the igneous and metamorphic area one cannot state categorically that oil prospects are entirely absent: but that is merely an example of the current limitations of certainty in these matters, complementary to the impossibility of promising definitely (in advance of drilling) that even the most favourably-indicated area will actually contain oil. The prospector can only list the prospects in an order of probability, and make his plans accordingly.

46. There is, of course, nothing scientifically abnormal in such a state of uncertainty regarding individual cases; the statisticians are quite accustomed to it, and a Life Assurance Company (for example) can make quite sound calculations based on group expectations, even though they remain uncertain about the extent to which any particular individual's life-span will correspond with normal expectations. In the case of oil prospecting, it will be realised, both the size of the statistical "population" and the knowledge of the relevant factors are so much smaller than for Life Assurance that prospecting remains an essentially speculative business.

47. It is worth considering whether any new development in technique might be expected to make a fundamental difference to the foregoing evaluation, and give a major increase in known resources. The one such innovation that seems at all possible is the invention of some means for making a direct determination from the surface of whether or not oil is physically present below the ground; even if it gave no indication about the size of the accumulation (a very important factor from the economic aspect) such a possibility would make a fundamental difference in our approach to the problem and would enormously widen the range of areas which it would be economically justifiable to test. But the fact remains that, in spite of occasional claims to the contrary, no such technique has yet been devised, and there is at present nothing to suggest that it may be forthcoming in any near future.

48. Failing a direct determination of oil in place, it would at least be a partial help if we could be certain of identifying oil source rocks when found; this would help in establishing the favourable prospects of a region. In spite of world-wide research in this matter, however, curiously little has been definitely established on this subject; and in practice it might not help us very much in deciding about test-wells in the Assam-Tripura belt.

49. There are a number of techniques which have recently been developed and applied particularly in regions where (as in some parts of the U.S.A.) practically all the possibilities of normal straight-forward surface inference have already been exhausted, and where there is still a high probability of obtaining oil if a suitably closed reservior remains concealed. Such techniques include studies on sedimentation and texture-analysis for the reconstruction of palaeogeography and the inference from them of the possible regional extent of oil-forming conditions and reservoir beds, including the possibilities of accumulations in stratigraphic traps.

50. Such studies (which in the U.S.A. are facilitated by a very large amount of regional underground evidence from oil borings) are not likely to be of major assistance in the Indian Union in the very near future: for we are still at the stage of exploring the possibilities of structures indicated by surface evidence (apart from anything that may be done in the alluvial areas), and only when some success in these provides the incentive to explore the more speculative possibilities of indirectly-indicated accumulations will these refined studies have any major application here. For the time being the eastern Tertiary belt offers a sufficiency of prospects of the more orthodox type for testing, and our first task is to make a determined effort to overcome the obstacles which have led eo such a relative lack of encouragement in past attempts. There seems every reason for sober hope that some measure of success will yet attend our efforts.

APPENDIX A

List of of Test Wells in the Indian Union

Year Started	District	Locality	Well		
			No.	Drilled by	Depth
1866	Upper Assam	Jaipur	1	McKillop Stewart & Co.	102
			2		171
			3		162
1867	,,	Makum	4	McKillop Stewart over & Co.	143
			5		82
			6		32
1888	,,	,,	1 11	Assam Railways & Trading Co.	110 to 1241
1889	,,	Digboi	1	Assam Railway & Trading Co.	662
1891	,,	,,	2		720
			3		752
1892	,,	,,	4		910
1901	Surma Valley	Badarpur	1	W. G. Stoker	130
1909	,,	Khasimara	1	Preo Nath Sen	106
			2		192
1910	,,	Khasi	1	Mackenzie	25
1911	,,	Badarpur	2	Local Syndicate	730
1911			1	Government	20
1912	Gulf of Cambay	Gogha	2		430
1915			3		1016
	Surma Valley	Mahakhal	1	Assam Burma Petro Co.	(Shallow)
1913	,,	Badarpur	1	Budderpore Oil C.	677
1915	,,	,,	2	Burmah Oil Co.*	943
1915	Malabar Coast	Alleppey	1	Darrah Smail Co.	130
1918	,,	Narrakal	1	Cochin State	103
1918	Surma Valley	Masimpur	1	Burmah Oil Co.	1540
1918	Upper Assam	Makum	12	Assam Oil Co.	869
			13		685
			14		837
1920	Surma Valley	Masimpur	2	Burmah Oil Co.	3028
1920	Upper Assam	Balijan	1	Assam Oil Co.	719
1920	Surma Valley	Hilara	1	Burmah Oil Co.	2100
1920	Upper Assam	Namchik	1	Assam Oil Co.	592
			2		914
1921?	Gulf of Cambay	Jagatia	1-7	Baroda State	76-185
1921 1922	Gulf of Cambay	Baroda	1-7	State	147-622
1922	Surma Valley	Chhatachura	1	Burmah Oil Co.	2892
1922	,,	Kanchanpur	1	Burmah Oil Co.	2331
1922	,,	Masimpur	1	Burmah Oil Co.	3244
1923	Upper Assam	Barjan	1	Assam Oil Co.	1724
1923	,,	Namchik	3	Assam Oil Co.	837
1923	Surma Valley	Patharia	1	Burmah Oil Co.	2871
1925	Upper Assam	Baragolai	1	Assam Oil Co.	5545
1925	,,	Dhekiajuli	1	Assam Oil Co.	3925

1925	Surma Valley	Masimpur	4	Burmah Oil Co.	3293
1926	Gulf of Cambay	Baroda	6	State	179
1926	Upper Assam	Dilli	1	Assam Oil Co.	439
			2		329
1926	,,	Ki Ker	1	Whitehall Petr. Corp.	2016
1926	,,	Nichuguard	1	Whitehall Petr. Corp.	1000
			2		1900
1927	Surma Valley	Patharia	2	Burmah Oil Co.	3436
1929	Gulf of Cambay	Baroda	7	State	231
			8		383
1930	Upper Assam	Bandersulia	1	Burmah Oil Co.	2757
1931	Surma Valley	Madimpur	5	Burmah Oil Co.	7685
1935	Gulf of Cambay	Gogna	1	Chinoy	960
1935	,,	Hajat	1	Chinoy	
1949	Upper Assam	Tiru Hills	1	B.O.C. (I.C.) Ltd.	3500

*Burmah Oil Co.—as the Burmah Oil Co. (India Concessions) Ltd. was then known.

NOTE. This list has been compiled from various sources, and is probably not exhaustive. It does not include the drilling at Digboi and Badarpur fields designed to extend their proved areas after initial confirmation, nor the large number of core-holes drilled only for structural and stratigraphical information without any expectation of oil possibilities.

APPENDIX B.

Selected Bibliography

1. *Capito, C. E.* "The oil-wells of Assam." Proc. Inst. C. Eng., Vol. CLXXXV, 363-378, (Abst. Journ. I.S.Inst. LXXXV, 477)—1911.
2. *Coates, J.* "The Construction of Geological Sections". Proc. 32nd Ind. Sci. Cong. (3) 56; and Q.J. Geol. Min & Met. Soc. Ind., Vol. XVII, (1), 1-11—1945.
3. *Corps, E. V.* "Digboi Oil Field, Assam". Bull. Amer. Assoc. Petr. Geol., Vol. 33 No. 1-1949.
4. *Evans, P.* "The Tertiary Succession in Assam". Trans. Min. & Geol. Inst. Ind. Vol. XXVII (3)—1932.
5. *Evans, P. and Crompton, W.* "Geological Factors in Gravity Interpretation Illustrated by Evidence from India and Burma". Q. J. Geol. Soc. Lond. Vol. CII, pp. 211-249—1946.
6. *Evans, P. and Emrick, B. R.* "Drilling and Fishing under Pressure at Masimpur, Assam". J.Inst. Petr.Techn., Vol. 22, 187-188—1936.
7. *Evans, P., Hayman, R. J., & Majeed, M.A.* "The Graphical Representation of Heavy Mineral Analyses". Proc. 20th Ind. Sci. Cong., 347; Proc. World Petroleum Congress London, Vol. 1, 251-256. (Also Q.J.Geol.Min&Met.Soc.Ind., Vol. VI(2), 27-34, 1934)—1933.
8. *Evans, P., and Majeed, M.A.* "The Heavy Minerals of the Assam Tertiaries". Proc. 25th Ind. Sci. Cong., (3) III—1938.
9. *Evans, P., and Vachell, E. T.* "Gravity Measurements in India". Proc. 29th Ind.Sci.Cong. (3) 123—1942.
10. *Evans, P., and Vachell, E. T.* "Some Gravity Problems of Eastern India". Proc. 29th Ind.Sci.Cong. (3) 123—1942.
11. *Hannay, P. S.* "On the Assam Petroleum Beds." Journ. A.S.B. XIV, 817-821 —1845.
12. *Hughes, T. W. H.* "Petroleum in Assam". Rec. G. S. I. VII, 55-58—1874.
13. *Rankine, A. O., and Evans, P.* "Geophysical Prospecting for Oil in India". Minerals Research Symposium. Nat.Inst. of Sc. of Ind. 1945.
14. *Pascoe, E. H.* "The Petroleum Occurrences of Assam and Bengal". Mem. G. S. I. Vol. XL (2)—1914.
15. *Wadia, D. N.* "Petroleum Resources of India". Special Publication No. XI of Ind.Assoc. for Cult. of Sc. Also in "Indian Minerals" Vol. I No. 4 and Vol. II
16. *Wilson, G. F.* "Drilling of a Deep Pressure Test in India". J.Inst.Petr.Techn. Vol. 23, 401-407—1937.

37th INDIAN SCIENCE CONGRESS, POONA, 1950

SECTION OF BOTANY

PRESIDENT: P. MAHESWARI, D.Sc., F.N.I.

Presidential Address

"CONTACTS BETWEEN EMBRYOLOGY, PHYSIOLOGY AND GENETICS"

In addressing you today I must first remind you of those members of the Botany Section who have passed away since we met last. Prof. Birbal Sahni F.R.S., who presided over this section in the years 1921 and 1938, and over the Geology section in the year 1925, and was also the General President of the Indian Science Congress Association in 1940, had been the leading botanist of our country for nearly three decades. He and his pupils contributed many papers to these meetings and his presence always illumined our proceedings. Prof. J.F.R. D'Almeida, who was Recorder for this session, was an authority on ferns and carried out important taxonomic work on the flora of the Bombay Presidency.

Ladies and gentlemen, I would request you to stand for a couple of minutes to honour the memory of these men.

As I looked over the addresses of the previous presidents of this section, I found that they had dealt with an extremely varied assemblage of subjects covering almost all branches of botany. I find only one noteworthy exception —the science of Plant Embryology. My election to the Presidentship was probably to fill this gap. I would request you to bear with me in my humble attempt towards this end.

There is an impression in the minds of some people that embryology is a purely descriptive study of embryo sacs and embryos. Five years ago (Maheshwari, 1945), in an address read before the Indian Botanical Society, I attempted to indicate the importance of embryological studies in the solution of phylogenetic problems. Today I wish to discuss the vast openings for research which exist in the field of Experimental Embryology and the contacts which this has with Physiology, Genetics and Plant Breeding.

THE BARRIERS TO CROSSABILITY IN PLANTS

Ever since the rediscovery of Mendel's laws in 1900, breeders have been increasingly active in crossing different varieties, species and genera with a view to producing newer and more useful types. But since the germ cells of angiosperms are not free-swimming structures, there are many processes which have to be undergone before gametic fusion can take place. Indeed, as Focke (1881) said in his well-known book entitled "Die Pflanzenmischlinge," only a carefully planned series of experiments can show whether two plants will hybridize or not.

What are the breeder's difficulties in his attempt to cross two plants? There may be a disharmony in the time of flowering of the two parents, or flowering may be too infrequent. One of the plants may be a native of one country and another of a different country thousands of miles away. The pollen may refuse to germinate on the stigma. The pollen tubes may burst or die in the style or grow too slowly to reach the ovules in time. The generative cell may fail to divide; and even if it divides the sperm may fail to fertilize the egg. Or, syngamy takes place but the polar nuclei are not fertilized resulting in lack of endosperm. Finally although fertilization takes place normally, the development of the embryo may be arrested at an early stage so that no viable seeds are produced.

INFREQUENT FLOWERING OR DISHARMONY IN TIME OF FLOWERING OF THE PARENTS

When there is only a slight disparity in the flowering season of the two parents, it is usually possible to overcome the difficulty by making small adjustments in the time of sowing or by retaining the crop in off season. In cold countries the late flowering plants are often transferred to a hothouse to hasten their blooming. Or, early sowing may be resorted to. In dealing with an early flowering variety, the reverse measures may naturally be used with advantage.

When the disparity is of a higher order or flowering is infrequent, special methods must be used. In many cases the vegetative phase can be broken or shortened and the reproductive phase initiated by altering the environmental conditions. Changes in photoperiod, temperature, and nutrition are some of the devices which may be used for this purpose.[1]

Recently, chemical treatments have been used with the same object. Zimmerman and Hitchcock (1942, 1949) report that under the influence of tri-iodobenzoic acid, applied to the soil or sprayed on to the plants themselves, axillary buds of tomato which normally produce leafy shoots can be induced to grow flower clusters. The main stem of the plant also loses the shoot producing bud and terminates in an inflorescence. Very spectacular results have been obtained by Van Overbeek (1946) on pineapples. Normally pineapples of the Calezona variety flower in Hawai in December, but applications of 0.25-0.50 mg. of naphthalene acetic acid could induce flowering at any time of the year. The treatment is simple. A few drops of the solution are applied to the centre of the crown. Flowers appear in about 7 weeks after treatment and the fruits are ready for harvesting approximately 13 weeks later.

The work done by several other authors (Thimann and Lane, 1938; Stier and du Buy, 1938; Green and Fuller, 1948; Leopold and Thimann, 1949) seems to confirm that while large doses of auxins inhibit or delay flowering, very weak concentrations of the same promote it. This is a very fruitful field of research which will no doubt be turned to great economic advantage in future years.

STORAGE OF POLLEN[2]

When the two parents are widely separated from each other both in time (of flowering) and space, a very useful device is to store the pollen and transport it from one place to another. Date pollen is said to retain its viability for a whole year and used to be an important article of commerce in the past . Most pollens, however, remain viable only for a few days or weeks and the range of variation in this respect may be illustrated by a few examples from common plants. In *Hordeum* (Anthony and Harlan, 1920) and *Oryza* (Nagao and Takano, 1938) fertilization cannot be secured with certainty unless the pollen is transferred directly from the anther to the stigma. In *Sorghum* (Stephens and Quinby, 1934) no seed could be obtained when pollen was used five hours or more after collection. In some experiments at Coimbatore 65 per cent of the pollen grains of *Gossypium* were found to retain their viability up to the 24th hour but none after twice this period (Banerji, 1929). At New Delhi the pollen of *Solanum melongena* remains viable for only one day in summer and two to three days in winter (Pal and Singh, 1943).

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[1] For further information see Gregory (1948) and Hamner (1948).

[2] For a more detailed treatment of this topic see Maheshwari (1944).

Recent work has shown that whatever the viability might be under natural conditions, it can almost always be prolonged to an appreciable extent by storing the pollen under proper conditions. Holman and Brubaker (1926), who have reviewed the older literature, mention the extension of longevity of *Cyclamen* pollen from 18 to 185 days and that of *Listera ovata* from 40 to 164 days. Samples of *Typha* pollen, which had been stored in a calcium chloride desiccator for 71, 94, 116 and 158 days, gave respectively 75, 70, 65 and 56 per cent germination, and 2 per cent of the pollen grains remained viable even after 336 days. Air dry pollen of *Coffea* stored in the ordinary way loses its germination power within a week but when kept in a desiccator it retains the same for over a month (Ferwerda, 1937). Pfeiffer (1944), who made similar experiments with *Cinchona*, found that 5 to 19 per cent of the pollen retained its viability even after a year's storage in darkness at a temperature of 10°C. and a humidity of 35 to 50 per cent. Nebel (1939) has been able to preserve apple pollen for four and a half years and sour cherry pollen for five and a half years at a temperature of 2—8°C. and a humidity of 50 per cent. Even grass pollen, which is notoriously ephemeral, has been kept alive for 15 to 30 times the period of its natural viability. To mention only two examples, the pollen of *Saccharum spontaneum* (a wild cane used in crosses with the cultivated canes) spread out on a watch glass in diffused light remained viable for only about six hours; that stored in vials plugged with cotton and kept at room temperature for 12 to 24 hours; and the same kept at 7°C. for more than a week (Sartorius, 1942). Similarly, the pollen of *Zea mays* stored in pollinating bags in direct sunlight at a maximum temperature of 46°C. remained viable for only three hours; that stored in shade at a maximum temperature of 30°C. for 30 hours; and the same kept in tassel at a temperature of 4.5°C. and a relative humidity of 90 per cent for eight to nine days (Jones and Newell, 1948).

The data given above indicate that the most important factor in pollen storage is temperature and the next is relative humidity. Strong light is harmful and diffused light or even complete darkness seem to be more conducive to successful storage.

Receptivity of the Stigma

Equal in importance to the viability of pollen is the receptivity of the stigma, but this is less amenable to control. In most plants the stigma is

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3. Stout (1924) contradicts this and says that he found no evidence of survival of air dry date pollen for more than 77 days, but as pointed out by Holman and Brubaker (1926) it is possible that under favourable conditions the period may be much longer.

receptive for only a short period and if the pollen is not transferred to it at the right time, it fails to germinate or the germination is so slow that the flower withers and falls off before the pollen tubes can reach the ovules. Attempts to prolong the receptivity of the stigma have usually been unsuccessful; or, they are associated with secondary effects which make it difficult to derive much benefit from such prolongation. For instance, although a lowering of the temperature can lengthen the blooming period and also extend the period of receptivity of the stigma to a certain extent, it has an adverse effect on the rate of growth of the pollen tube so that the net gain is practically nil.

MECHANICAL DEVICES FOR BRINGING THE POLLEN GRAINS OR POLLEN TUBES IN PROXIMITY TO OVULES

In most cases the difficulty is not so much in the initial germination of the pollen as in the subsequent growth of the pollen tubes in a foreign style. This may be due to two reasons: (*a*) the maximum length attainable by the pollen tubes of the male parent is inadequate for enabling them to reach the ovules, and|or (*b*) the unfavourable medium through which they have to make their way causes an excessive retardation of their growth. Two examples may be cited. When the long-styled flowers of *Datura* are pollinated with pollen from short-styled flowers, many of the pollen tubes burst and fertilization is rendered improbable (Buchholz *et al*, 1935). When the self-sterile *Brugmansias* (Joshi, 1948) are self-pollinated, the pollen grains germinate freely but only a few pollen tubes grow beyond the stigmatic region. The maximum distance traversed by them during the several days before the flowers drop off does not exceed more than one fourth the length of the style. In cross-pollinations, on the other hand, the pollen tubes grow normally and viable seeds are produced.

When failure of a cross is due to such causes, one obvious remedy is to amputate the style and reduce it to suitable length. In a cross between *Zea* and *Tripsacum* Manglesdorf and Reeves (1931) shortened the style of the former to a length suitable for the pollen tube of *Tripsacum* and thereby obtained intergeneric hybrids. However, since the cut end of the style is not always so suitable for pollen germination as the stigma, sometimes it is desirable to use a different method in which the middle portion of the style is removed and the upper and lower portions are then joined together and held in place (Buchholz, Doak and Blakeslee, 1932). [4]

A Japanese worker, Yasuda (1931), has gone one step further and attempted an actual graft of the style upon the [5] ovary in *Petunia violacea* He cut off the style of one flower and glued it with gelatin to the ovary of another whose style had been previously cut away. In order to prevent the falling apart of the grafted style, he supported it against an iron wire tying the support and the style with a spider's thread. When the operation was successful, the grafted style grew normally and attained its usual size. On the other hand, if the tissues failed to unite, the style turned brown and soon withered away.

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4. Sanz (1945) introduced pollen inside vertical slits cut in the tops of decapitated styles of *Datura*.

5. In this species there are several self-sterile races. Pollen tubes from own pollen grains are too slow in their growth, but those from pollen grains of other races grow normally and effect fertilization.

Yasuda's method requires a great deal of manipulative skill and has apparently never been tried by any other worker. Although it seems to be impracticable with plants having thin styles, it can perhaps be used with profit when the styles are reasonably thick. A grafting of the style of the species used as the paternal parent to the ovary of the maternal parent is certainly a promising method of combating the incompatibility between two species or varieties.

A further improvement would be to devise some method of introducing the pollen grains directly into the ovary.[6] Somewhat reminiscent of the artificial insemination practised in animals, this technique has not so far been perfected for plants. That it is entirely possible to do so, however, is indicated by some experiments of Dahlgren (1926) who succeeded in bringing about fertilization of the ovules of *Codonopsis ovata* by this method. More recently, Bosio (1940) tried some "intravarial pollinations" in *Helleborus* and *Paeonia.* He emasculated the flowers and either removed the stigmas or painted them with celloidin. Then an incision was made in the ovary and the pollen grains introduced into it artificially. In *Helleborus* the germination was inadequate to cause any fertilization but in *Paeonia* several ovules were fertilized yielding viable seeds. In explanation of this difference in the behaviour of the two genera, the author says that the pollen of the Ranunculaceae requires for its germination a sugary medium with a pH close to neutral. Within the ovary of *Helleborus* there is no free liquid and the pH of the cells lining it is about 4; in *Paeonia,* on the other hand, the cells at the base of the ovarian cavity secrete an abundant liquid which has a suitable concentration of sugar and a pH of about 6. Germination of the pollen, therefore, fails in the former but is quite successful in the latter. In nature it occurs in both cases, since the stigma fulfills the required conditions.

CHEMICAL STIMULATION OF POLLEN TUBE GROWTH

Breeders sometimes use "bud pollination" to achieve a difficult cross. The increased fertility obtained by this method has been attributed to two factors. One is that it gives more time to the pollen tubes to reach the ovules. The second is that possibly the mature style and stigma secrete certain substances which inhibit the growth of the pollen tubes; by bud pollination the breeder circumvents this trouble and catches the stigma at a time when the secretion has not yet begun to take place.

However, bud pollination is not always successful. Pollen frequently fails to germinate on an immature or unreceptive stigma, and a better method would be to encourage the growth of the pollen tubes by the application of suitable chemicals either to the pollen grains or to the stigmas. P. F. Smith (1942) has shown that in artificial cultures 3-indoleacetic acid, in concentrations of one in a million, appreciably stimulates the germination of the pollen as well as the rate of elongation of the pollen tubes. Addicott (1943) has reported that several substances including vitamins, plant hormones, pyridines and puriness produce similar effects. Löve and Löve (1945) state that animal sex hormones, both male and female, have a stimulating effect on the growth of pollen tubes. In pollen tube cultures of *Rumex tenuifolius,* treated with oestron and ostradiol, this effect was found to be especially pronounced as the length of the tubes was 63 and 71 per cent greater than in the controls.

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[6] Intraovarial pollen grains have been reported in nature in *Butomopsis* (Johri, 1936), *Erythronium* (Haque, 1949), and *Trillium* (Johri and Eunus, 1950), but it is not certain if they germinate inside the ovary and cause fertilization.

More recently Huang (1948) has found that in *Prunus armeniaca, P. persica* and *Pinus massoniana* the addition of micro-elements (except CuSo4) to the culture medium is markedly favourable for pollen germination and pollen tube growth, and that vitamins, some amino acids and other organic acids also moderately stimulate both germination and tube elongation.[7]

What has been found true of artificial cultures is also applicable to plants in the field. Eyster (1941) has reported that the self-incompatibility in *Petunia, Tagetes, Trifolium repens* and *Brassica oleracea* can be counteracted by spraying ∝-napthalene acetamide immediately before or shortly after pollination. This chemical is said to "neutralize the effects of an ovarian secretion which diffuses into the style and inhibits or greatly retards the growth of pollen tubes." Emsweller and Stuart (1948) have confirmed this in the case of *Lilium longiflorum,* a species composed of self-incompatible clonal groups which fail to set seed on self-pollination. The application of 1 per cent naphthalene acetamide was found to be of great advantage not only in overcoming self-incompatibility but also in facilitating some intra and interspecific crosses which were otherwise very difficult.[8]

INCOMPATIBILITY IN RELATION TO CHROMOSOME NUMBER OF THE TWO PARENTS

Sometimes a change in the chromosome number of one of the parents has a remarkable effect in the inactivation of incompatibilities. As the result of a series of controlled pollinations, Stout and Chandler (1941) and Stout (1944) showed that the potentially fertile flowers of *Petunia axillaris* are wholly self-incompatible and produce no seeds or capsules on self-pollination. However, the self-pollinated flowers of tetraploid branches (produced by colchicine treatment) produced large well-filled capsules. Flowers on the self-incompatible diploid branches also produced capsules when pollinated from flowers of tetraploid branches on the same plant, but tetraploid x diploid combinations on the same plant failed to yield any seeds.

Of interest in this connection are also some observations of Buchholz and Blakeslee (1929), Satina (1944), and Blakeslee (1945) on *Datura.* When pollen from a *2n* plant is applied to the stigma of a *4n* plant, fertilization takes place freely and some viable seeds are also produced ; but in the reciprocal cross when pollen is applied from a *4n* plant to a *2n* stigma, seed formation is extremely rare. Histological studies have shown that the pollen tubes derived from the *4n* male parent burst in the *2n* styles and never reach the ovary (see also Handler, 1948). It was possible, however, to overcome this difficulty and change the *2n* x *4n* cross from an incompatible to a compatible one in an ingenious way. Treatment with colchicine usually results in periclinal chimaeras in *Datura.* Some of these have the doubled chromosome number in the epidermal layer but not in the underlying tissues. Since it is the epidermal layer which forms the transmitting tissue in the style of *Datura,* a periclinal chimaera with a a $4n$ epidermis should react exactly like a pure $4n$ parent so far as its relation to pollen tubes from a $4n$ male parent is concerned. This was actually found to be the case and diploid pollen tubes from $4n$ males grew readily without bursting in styles of a periclinal chimaera with a $4n$ epidermis. From his work on *Nicotiana,* Kostoff (1934) also concludes that "pollen-tubes, originating from species that have larger chromosome number, grow slower in the styles of species having smaller chromosome number, than those originating from species with smaller chromosome number, when grown in styles of species with larger chromosome number, Consequently, a species cross A x B would be more successful than its reciprocal B x A, when A has a larger chromosome number than B, because the pollen-tubes of B reach easier the ovary of A than in the reverse cross.[9]

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[7] See Vasilyev (1937) on the importance of boron in the growth of pollen tubes of apple and pear; he suggests its use in spray form on the trees in order to obtain a higher fruit set. Svolba (1942) stresses the importance of pH value.

[8] Lewis (1942) reports that in incompatible pollinations in cherry (*Prunus avium*) the application of ∝-napthalene acetamide, either in aqueous solutions or in lanolin smears, had no effect on the rate of pollen tube growth, but it delayed the formation of an abscission layer at the base of the style thereby allowing a longer time to the incompatible tubes to reach the ovary.

FAILURE OF FUSION OF THE MALE AND FEMALE NUCLEI

Finally, there remains the difficulty that even after the pollen tubes have reached the ovary and ovules, fertilization may fail to occur for some obscure reason. A couple of examples may be mentioned. When the flowers of *Ribes nigrum* are selfed, the pollen tubes enter the ovules and "even lay themselves against the embryo-sac nucleus" but the male and female nuclei do not fuse and hence no seeds are formed (Ledeboar and Rietsema, 1940). In plants of *Oxalis cernua* (Krupko, 1944) growing in the Mediterranean region, the pollen tube enters the embryo sac and discharges its nuclei, but fertilization fails to occur.[10]

Since there is no known method of overcoming this trouble, it is not necessary to discuss the point further.

EMBRYO CULTURE

In the preceding pages we have considered the possibilities of overcoming some of the barriers to fertilization. It has frequently been observed, however, that even after gametic fusion has taken place something may arrest the growth of the embryo so that the resulting seeds are non-viable. To mention a few examples, in the cross *Datura stramonium* X *D. metel* (Satina and Blakeslee, 1935), the hybrid embryo degenerates after undergoing only two or three divisions. In the cross *D. pruinosa* X *D. metel* the primary endosperm nucleus undergoes several divisions but the zyote usually remains undivided. In two other crosses, *D. meteloides* X *D. discolor* and *D. ceratocaula* X *D. meteloides* (Sachet, 1948), most of the ovules are fertilized and the endosperm and embryo at first develop normally, though rather slowly. After the embryo has reached the spherical stage, the endosperm starts disintegrating accompanied by the enlargement and active division of the cells of the integumentary tapetum or endothelium lying just outside it. This layer forms a voluminous mass which invades the cavity of the embryo sac and replaces the endosperm. The embryo survives in this mass for a few days but does not undergo further divisions. Ultimately it degenerates and disappears and no viable seeds are produced.

Recent research has shown that in such cases it is frequently possible to excise the young embryos from the ovules and grow them in artificial media—a process not unlike the well-known Caesarean operation in which an immature animal embryo is removed from the body of the mother and grown in an incubator.

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[9] See also Fagerlind (1944) who concludes that generally there is a greater compatibility when the chromosome number of the maternal parent exceeds that of the paternal.

[10] Apogamic embryos are, however, formed quite frequently in the micropylar part of the embryo sac.

In tracing the development of this new technique of embryo culture we find that Hannig (1904) was the first to have made a successful attempt of this kind. Using certain crucifers (*e.g., Raphanus* and *Cochlearia*) as the objects of his study, he tested a variety of nutrient media containing sugars, mineral salts, plant decoctions, certain amino acids and gelatin. Mature plants were reared from embryos only 1.2 mm. in length at the time of excision, although presumabaly the radicle, plumule and cotyledons had already been formed at this stage. Stingl (1907) grew embryos of several cereals, but instead of placing them in culture media he transferred them to the endosperms of other genera of the family.[11] Dietrich (1924), who experimented some years later with a larger variety of plants than any of his predecessors, found that Knop's solution with 2.5 to 5 per cent cane sugar and 1.5 per cent agar enabled prompt growth of immature embryos of several species. He further observed that the cultured embryos tended to skip the stages of development which had not been completed at the time of excision and grew directly into seedlings. However, his efforts to cultivate very young embryos, less than one-third of their mature size, were unsuccessful.

The work of Hannig, Stingl and Dietrich, although of great importance, seems to have been prompted more by curiosity than any other reason, and the possibility of using the method to economic advantage was first pointed out by Laibach (1925, 1929). While making some interspecific crosses in the genus *Linum,* he found that the cross *L. perenne* x *L. austriacum* yielded fruits of approximately normal size but the seeds were greatly shrunken and only about half as heavy as the normal seeds. By dissecting out the embryos and placing them upon damp blotting paper he was able to induce their germination and the resulting plants flowered and fruited abundantly. The reciprocal cross *L. austriacum* x *L. perenne* was more difficult, for here the fruits shed prematurely when the seeds had only one-thirteenth of the weight of normal seeds and were incapable of germination. However, by excising the embryos when they were about a fortnight old and placing them in little tubes on cotton wadding containing 10-15 per cent cane sugar, he was able to promote their growth. A couple of weeks later they were removed from the sugar solution and placed on moist blotting paper, where they germinated within a few days and eventually yielded vigorous plants which flowered and fruited normally. Laibach, therefore, expressed the opinion that a similar method of "artificial premature birth" could perhaps be used to obtain offspring from various other crosses which had so far proved unfruitful. In conclusion he said: "In any case, I deem it advisable to be cautious in declaring combinations between higher plants to be unviable after fertilization has taken place and after they have begun to develop. Experiments to bring the aborted seed to development should always be undertaken, if it is desirable for theoretical or practical reasons. The experiments will not always be successful, but many a result might be obtained by studying the conditions of ripeness of the embryos and by finding out the right time for the preparing out of the seeds."

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[11] Recently Camara (1943) has performed a number of similar transplantation experiments with cereals. It is interesting to note that embryos of *Triticum vulgare* grew better on endosperm of *Secale* than on that of *T. durum* or *T. turgidum.*

Laibach's brilliant exposition gave the lead for more intensive work on the artificial culturing of embryos and during recent years a number of papers have appeared on the subject. In several crosses, which were formerly unsuccessful, the hybrid embryos have now been reared to maturity.

In mentioning some specific cases where this technique has been used with success, we may first refer to certain stone fruits, such as *Prunus avium* (sweet cherry), *P. domestica* (plum) and *P. persica* (peach). When early ripening varieties of these plants are used as female parents, the embryos abort and the seeds are not viable. Tukey (1944) made artificial cultures of the embryos and grew mature plants from them. The procedure adopted was to split the stony endocarp with a scalpel, cut carefully through the integuments, nucellus and endosperm, and drop the embryos under aseptic conditions into bottles containing nutrient agar. The seedlings arising from them were first transplanted to sterile sand watered with a nutrient solution and then to soil. In time, they developed into vigorous fruiting trees.

To mention a few other examples Jφrgensen (1928) used the embryo culture method to obtain hybrids between *Solanum nigrum* and *S. luteum ;* Bensley (1930) between *Gossypium hirsutum* and *G. herbaceum ;* Skirm (1942) between some species of *Prunus* and of *Lilium ;* Brink, Cooper and Ausherman (1944) between *Hordeum jubatum* and *Secale cereale ;* Smith (1944) between *Lycopersicon esculentum* and *L. peruvianum ;* Iwanowskaya (1946) between *Triticum durum* and *Elymus arenarius ;* and Sanders (1948) between several species of *Datura.*

Since conditions favorable for the growth of the embryos are also favorable for the growth of various bacteria and fungi, proper precautions have of course to be taken both at the time of dissection of the embryos and during their transfer to the culture medium to save the cultures from contamination.

A most important factor is the composition of the medium. Older embryos are largely autotrophic and usually present little difficulty. The present problem, however, is to try to rear embryos in younger stages of development. Frequently the minute embryo dies in culture or growth results in the formation of callus like tissue only.

While it must be therefore be admitted that there are difficulties in embryo culture which still need to be conquered, there is no doubt that the concentrated attack which is being made on the problem under the leadership of Blakeslee, La Rue, Brink, and others will help to overcome them. Embryo culture has proved to be of great economic value not only in the achievement of a much wider range of hybrid combinations than was possible up to this time, but also in the quick germination of seeds which normally require a dormant period of months and years so that the breeder is saved the uncertainty and delay which troubled him previously. [12]

Induced Parthenogenesis

Finally, we come to the problem of inducing the development of embryos from unfertilized eggs. In normal fertilization the sperm imparts not only the activating stimulus but also a set of genes embodying the contribution of the male parent towards the make-up of the new individual. The prime interest in induced parthenogenesis lies in the fact that if the stimulus can be provided without the usually accompanying paternal genes, it would greatly facilitate the task of the geneticist in producing a homozygous true-breeding type which otherwise requires a long and laborious process of self-fertilization (East, 1930).

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[12] Since excised embryos skip this period of dormancy, the embryo culture method can also be used to make tests of the germinating capacity of seeds. The non-viable embryos become discolored and soon deteriorate while the viable embryos show various degrees of hypocotyl development and cotyledon enlargenment and become green in colour (see Barton and Crocker, 1948).

Ever since the initial discovery of a *Datura* haploid (Blakeslee *et al,* 1922), a variety of physical and chemical treatments have been tried to produce haploids artificially. The chief of these are: (*a*) exposure of flowering shoots to very high or very low temperatures or to x-rays (*b*) use of x-rayed or of foreign pollen on stigma; (*c*) delayed pollination; and (*d*) chemical treatment.

To give an exhaustive survey of the successes and failures that have attended these efforts is beyond the scope of this address and will not be attempted. A few examples are mentioned, however, to indicate the nature of work that has been done.[13]

Concerning the effect of temperature, it is interesting to not that Müntzing (1937) obtained a haploid plant of *Secale cereale* by exposing the spikes to low temperatures (0.3°C), while Nordenskiod (1939) did the same by exposing them to high temperatures (41°-42C)[14].

Kihara and Katayama (1932) obtained three haploids of *Triticum monococcum* from spikes which had been exposed to X-rays at the time of meiosis. Later, Katayama (1934, 1935) pollinated the stigmas with X-rayed pollen and out of 91 seedlings raised by him 16 turned out to be haploids. However, most other workers have been far less successful, and Smith (1946) categorically states that he failed to obtain any increase in the number of haploids by X-ray treatment.

The use of foreign pollen for inducing haploidy was first brought into prominence by Jϕrgensen (1928) work on *Solanum nigrum.* Following interspecific or intergeneric crossings, the formation of haploid embryos has also been reported in *Brassica* (Nogouchi, 1928), *Oenothera* (Gates and Goodwin, 1930), *Triticum* (Nakajima, 1935) and a few other plants.

Kihara (1940) found that in *Triticum monococcum* the frequency of haploids could also be augmented by merely delaying the time of pollination. By applying pollen on the sixth day after emasculation he obtained two haploids among 10 plants, on the seventh day four haploids among 44 plants, on the eighth day five haploids among 18 plants, and on the ninth day three haploids among 8 plants.

Yasuda (1940) injected aqueous solutions of "belvitan" in the ovaries of *Petunia violacea.* In ovules fixed and sectioned three days after treatment he observed some striking changes. In some cases the nucellar cells[15] were found to have enlarged as the result of such stimulation; in others the egg had divided once or twice forming a small proembryo; and in still others the antipodal cells had increased in volume. In explanation of the fact that division occurred only in the egg and the other cells merely enlarged, the author says that belvitan promotes cell-division, in embryonic cells while in mature cells it causes only a growth of the cell-wall.

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[13] For further information see reviews by Ivanov (1938) and Kostoff (1942).

[14] By similar treatment in mammals seven parthenogenetic rabbits have been produced, six by treatment of the eggs with heat hypertonicity *in vitro* and subsequent implanation in a prepared doe (Pincus, 1939 a, b), and one by cooling exposed fallopian tubes containing eggs (Pincus and Shapiro, 1940).

[15] These must really be the cells of the integumentary tapetum, for the nucellus disorganizes at an early stage in all member of the Solanaceae.

Yasuda's observations, although interesting, are still in a preliminary stage, for it is not clear whether the embryos he obtained were haploid or diploid nor does he mention if he succeeded in following them to later stages of development.

It must therefore be confessed that so far we have not succeeded in finding a suitable method for inducing parthenogenesis in higher plants. Although exposure to temperature extremes and other shocks and pollination with X-rayed or foreign pollen have apparently given some positive results in special cases, the number of parthenogenetic plants obtained by these methods is too small to warrant the deduction of a definite causal relationship between the treatment and results. What is really needed is an agent for producing haploid plants which will give positive results with approximately the same consistency as colchicine does in producing polyploidy. A logical method of approaching the problem would be to know what are the changes that take place inside the embryo sac in known cases of haploid parthenogenesis and then attempt to duplicate them artificially. From the very meagre information that we possess in this regard it seems that although the egg can frequently be made to develop parthenogenetically, the real difficulty lies in an initiation of endosperm formation. It is for future research to suggest ways and means of overcoming this difficulty.

CONCLUSION

Ladies and gentlemen, the subject of my address has been rather wide. In the short time at my disposal I have only been able to touch upon some aspects of it, and those not in any way comprehensively. I hope, however, that what I have said will serve to indicate that the inactivation of incompatibilities, the artificial culture of immature embryos, and the production of haploid embryos from unfertilised eggs are problems of outstanding importance in applied and economic botany. Their solution requires the joint efforts of embryologists, cytologists, geneticists and physiologists. We need several teams of researchers in the Universities and in the Agricultural Institutes of our country to take up the work. I hope that it will receive the encouragement that it deserves.

LITERATURE CITED

ADDICOTT, F. T. 1942. Pollen germination and pollen tube growth as influenced by pure growth substances. Plant Physiol. *18*: 270-279.

ANTHONY, S. and HARLAN, H. V. 1920. Germination of barley pollen. Jour. Agri. Res. *18*: 525-536.

BANERJEE, I. 1929. Studies in cotton pollen. Agri. Jour. India *24*: 332-340.

BARTON, L. V. and CROCKER, W. 1948. *"Twenty years of seed research at Boyce Thompson Institute for plant research."* London.

BENSLEY, J. C. 1940. Hybridization of American 26-chromosome and Asiatic 13-chromosome species of *Gossypium.* Jour. Agri. Res. *60*: 175-182.

BLAKESLEE, A. F. 1945. Removing some barriers to crossability in plants. Proc. Amer. Phil. Soc. *89*: 561-574.

————BELLING, J., FARNHAM, M. E., and BERGNER, A. D. 1922. A haploid mutant in the Jimson weed, *Datura stramonium.* Science *55*: 646-657.

————and SATINA, S. 1944. New hybrids from incompatible crosses in *Datura* through culture of excised embryos on malt media. Science *99*: 331-334.

BOSIO, M. G. 1940. Ricerche sulla fecondazione intraovarica in *Helleborus* e *Paeonia.* Nuovo Giorn. Bot. Ital. N.S. *47*: 591-598.

BRINK, R. A., COOPER, D. C., and AUSHERMAN, L. E. 1944. A hybrid between *Hordeum jubatum* and *Secale cereale* reared from an artificially cultivated embryo. Jour. Hered. *35*: 67-75.

BUCHHOLZ, J. T. and BLAKESLEE, A. F. 1929. Pollen-tube growth in crosses between balanced chromosomal types of *Datura stramonium.* Genetics *14*: 538-568.

————DOAK, C. C. and BLAKESLEE, A. F. 1932. Control of gametophytic selection in *Datura* through shortening and splicing of styles. Bull Torrey Bot. Club 59: 109-118.

————WILLIAMS, L. F. and BLAKESLEE, A. F. 1935. Pollen tube growth of ten species of *Datura* in interspecific pollinations. Proc. Nat. Acad. Sci. U.S.A. *21*: 651-656.

CAMARA, A. 1943. Transplantacao de embrioes. Agron. Lusitana *5*: 375-386.

DAHLGREN, K. V. O. 1926. Svensk Bot. Tidskr. *20*: 97.

DIETRICH, K. 1924. Über Kultur von Embryonen ausserhalb das Samens. Flora *17*: 379-417.

EAST, E. M. 1930. The production of homozygotes through reduced parthenogenesis. Science *72*: 148-149.

EMSWELLER, S. L. and STUART, N. W. 1948. Use of growth regulating substances to overcome incompatibilities in *Lilium.* Proc. Amer. Hort. Sci. *51*: 581-589.

EYSTER, H. C. 1941. Pollen tube gowth of a self-sterile strain of *Petunia.* Proc. South Dacota Acad. Sci. *21*: 56-57.

FAGERLIND, F. 1944. Kompatibilität und Inkompatibilität in der Gattung *Rosa.* Acta Horti Bergiani *13*: 247-302.

FERWERDA, F. P. 1937. Keimkracht en levensduur van koffiestuifmeel, Arch. Koffiecult. Ned.—Ind. *11*: 135-150.

FOCKE, W. O. *"Die Pflanzenmischlinge."* Berlin.

GATES, R. R. and GOODWIN, K. M. 1930. A new haploid *Oenothera,* with some observations on haploidy in plants and animals. Jour. Genetics *23*: 123-156.

GREEN, M. and FULLER, H. J. 1948. Indole-3-acetic acid and flowering. Science *108*: 415-416.

GREGORY, F. G. 1948. The control of flowering in plants. Symposia Soc. Expt. Biol. *2*: 75-103.

HAMNER, K. C. 1948. Factors governing the induction and development of reproductive structures in plants. Symposia Soc. Expt. Biol. *2*: 104-116.

HANDLER, H. 1948. Triploid hybrids of three species of *Datura.* Amer. Jour. Bot. *35*: 798 s.

HANNING, E. 1948. Über die Kultur von Cruciferen Embryonen ausserhalb des Embryosacks. Bot. Zeitung *62*: 45-80.

HAQUE, A. 1950. The embryo sac of *Erythronium americanum* (in press).

HOLMAN, R. M. and BRUBAKER, F. 1926. On the longevity of pollen. California Univ. Publ. Bot. *13*: 179-204.

HUANG, T. 1948. Chemical stimulation in pollen germination and pollen tube growth. Bot. Bull. Acad. Sinica *2*: 282-290.

IVANOV, M. A. 1938. Experimental production of haploids in *Nicotiana rustica* L. Genetica *20*: 295-397.

IWANOWSKAYA, E. V. 1946. Hybrid embryos of cereals grown on artificial nutrient medium. Compt. Rend. (Doklady) Acad. Sci. URSS *54*: 445-448.

JOHRI, B. M. 1936. The life history of *Butomopsis lanceolata* Kunth. Proc. Indian Acad. Sci. B. *4*: 139-162.

JONES, M. D. and NEWELL, L. C. 1948. Longevity of pollen and stigmas of grasses: Buffalograss, *Buchloe dactyloides* (Nutt.) Engelm., and Corn, *Zea mays* L. Jour. Amer. Soc. Agron. *40*: 195-204.

JøRGENSEN, C. A. 1928. The experimental production of heteroploid plants in the genus *Solanum*. Jour. Genetics *19*: 133-211.

JOSHI, P. C. 1948. Self-sterility in three species of *Brugmansia*. Amer. Jour. Bot. *35*: 794 s.

KATAYAMA, Y. 1932. Haploid formation by X-rays in *Triticum monococcum*. Cytologia *5*: 235-247.

————1935. Karyogenetic studies on X-rayed sex cells and their derivatives in *Triticum monococcum*. Agri. Coll. Jour. Tokyo Imp. Univ. *13*: 333-362.

KENT, N. and BRINK, R. A. 1947. Growth in vitro of immature *Hordeum* embryos. Science *106*: 547-548.

KIHARA, J. 1940. Formation of haploids by means of delayed pollination in *Triticum monococcum*. Bot. Mag. Tokyo *4*: 178-185.

————and KATAYAMA, Y. 1932. On the progeny of haploid plants of *Triticum monococcum*. Kwagau *2*: 408-410.

KOSTOFF, D. 1934. Studies on the pollen-tubes. II. The dependence between the potency of pollen-tube growth in foreign styles and the thickness of the pollen-tubes and chromosome number. Curr. Sci. *2*: 464-466.

————1941. The problem of haploidy (cytogenetic studies on *Nicotiana* haploids and their bearings to some other cytogenetic problems). Bibl. Genetica *13*: 1-148.

KRUPKO, S. 1944. On the sterility of *Oxalis cernua* in the Mediterranean. Przyroda *1944*: 1-32.

LAIBACH, F. 1925. Das Taubwerden der Bastardsmen und die künstliche Aufzucht früh absterbender Bastardembryonen. Zeitschr. Bot. *17*: 417-459.

————1929. Ectogenesis in plants: methods and genetic possibilities of propagating embryos otherwise dying in the seed. Jour. Hered. *20*: 201-208.

LEDEBOER, M. and RIETSEMA, I. 1940. Unfruitfulness in black currants. Jour Pomol. & Hort. Sci. *18*: 177-180.

LEOPOLD, A. C. and THIMANN, K. V. 1949. The effect of auxin on flower initiation. Amer. Jour. Bot. *36*: 342-347.

LEWIS, D. 1942. Breakdown of self-incompatibility by naphthalene acetamide. Nature *149*: 610-611.

LOVE, A. and LOVE, D. 1945. Experiments on the effects of animal sex hormones on dioecious plants. Arkiv Bot. *32A* (13): 1-60.

MAHESHWARI, P. 1944. On the longevity of pollen. Indian Jour. Hort. *2*: 82-87.

————1945. The place of angiosperm embryology in research and teaching. Jour. Indian Bot. Soc. *24*: 25-41.

MANGELSDORF, P. C. and REEVES, R. G. 1931. Hybridization of maize, *Tripsacum* and *Euchlaena*. Jour. Hered. *22*: 319-343.

MUNTZING, A. 1937. Note on haploid rye plant. Hereditas *23*: 401-404.

NAGAO, S. and TAKANO, T. 1938. Duration of the preservation of the fertilization possibility in pollen and stigma of rice plant. Comm. Papers 30th Ann. N. Akemine: 88-92.

NAGOUCHIY, 1929. Zur Kenntnis der Befruchtung und Kornbildung bei den Res ipflanzen. Japanese Jour. Bot. *4*: 385-503.

NAKAJIMA, G. 1935. Occurrence of a haploid in *Triticum turgidum*. Japanese Jour. Genetics *11*: 246-247.

NEBEL, B. R. 1939. Longevity of pollen in apple, pear, plum, peach, apricot, sour cherry. Proc. Amer. Soc. Hort. Sci. *37*: 130-132.

NORDENSKIOD, H. 1939. Studies of a haploid rye plant. Hereditas *25*: 204-210.

PAL, B. P. and SINGH, H. B. 1943. Floral characters and fruit formation in the egg plant. Indian Jour. Genetics & Plt. Breeding *3*: 45-58.

PFEIFFER, N. 1944. Prolonging the life of *Cinchona* pollen by storage under controlled conditions of temperature and humidity. Contrib. Boyce Thompson Inst. *13*: 281-294.

PINCUS, G. 1939a. The comparative behavior of mammalian eggs in vivo and in vitro. VII. Further studies on the activation of rabbit eggs. Proc. Amer. Phil Soc. *83*: 631.

————1939b. The breeding of some rabbits produced by recipients of artificially activated ova. Proc. Nat. Acad. Sci. U.S.A. *25*: 557.

————and SHAPIRO, H. 1940. The comparative behavior of mammalian eggs in vivo and in vitro. VII. Further studies on the activation of rabbit eggs. Proc. Amer. Phil. Soc. *83*: 631-642.

SACHET, M. 1948. Fertilization in six incompatible species crosses of *Datura*. Amer. Jour. Bot. *35*: 302-309.

SANDERS, M. E. 1948. Embryo development in four *Datura* species following self and hybrid pollinations. Amer. Jour. Bot. *35*: 525-532.

————and BURKHOLDER, P. R. 1948. Effect of amino acids on growth of *Datura* embryos in culture. Amer. Jour. Bot. *35*: 797s.

SANZ, C. 1945. Pollen-tube growth in intergeneric pollinations on *Datura stramonium*. Proc. Nat. Acad. Sci. U.S.A. *11*: 361-367.

SARTORIS, G. B. 1942. Longevity of sugarcane and corn pollen—a method for long distance shipment of sugarcane pollen by airplane. Amer. Jour. Bot. *31*: 395-400.

SATINA, S. 1944. Periclinal chimaeras in *Datura* in relation to development and structure, (A) of the style and stigma, (B) of calyx and corolla. Amer. Jour. Bot. *31*: 493-502.

————and BLAKESLEE, A. F. 1935. Fertilization in the incompatible cross *Datura stramonium* x *D. metel*. Bull. Torrey Bot. Club *62*: 301-312.

SKIRM, G. W. 1942. Embryo culture as an aid to plant breeding. Jour. Hered. *33*: 210-215.

SMITH, L. 1946. Haploidy in einkorn. Jour. Agri. Res. *73*: 291-301.

SMITH, P. F. 1942. Studies of the growth of pollen with respect to temperature, auxins, colchicine and vitamin B1. Amer. Jour. Bot. *29*: 56-66.

SMITH, P. G. 1944. Embryo culture of a tomato species hybrid. Proc. Amer. Soc. Hort. Sci. *44*: 413-416.

STEPHENS, J. C. and QUINBY, J. C. Anthesis, pollination and fertilization in *Sorghum*. Jour. Agri. Res. *49*: 123-136.

STIER, H. L. and DE BUY, H. G. 1938. Influence of phytohormones on flower and fruit production of tomato. Proc. Amer. Soc. Hort. Sci. *36*: 723-731.

STINGL, G. 1907. Experimentelle Studie Uber die Entstehung von pflanzenlichen Embryonen. Flora *97*: 308-331.

STOUT, A. B. 1924. The viability of date pollen. Jour. New York Bot. Garden *25*: 101-106.

————1944. Inactivation of incompatibilities in tetraploid progenies of *Petunia axillaris.* Torreya *44*: 45-51.

————and CHANDLER, C. 1941. Change from self-incompatibility to self-compatibility accompanying change from diploidy to tatraploidy. Science *94*: 118.

SVOLBA, F. 1942. Beobachtungen bei Pollenkeimprufungen. Gartenbauwiss. *17*: 95-105.

THIMANN, K. V. and LANE, R. H. 1938. After-effects of treatment of seed with auxin. Amer. Jour. Bot. *25*: 535-543.

TUKEY, H. B. 1944. The excised-embryo method of testing the germinability of fruit seed with particular reference to peach seed. Proc. Amer. Soc. Hort. Sci. *45*: 211-219.

VAN OVERBEEK, J. 1946. Control of flower formation and fruit size in the pineapple. Bot. Gaz. *108*: 64-73.

VASILYEV, Y. P. 1937. The importance of boron for the process of fertilization. Sci. Fruitgrowing Mitchurinsk *1937*: 24-32.

WAARD, J. DE and RODENBURG, J. W. M. 1948. Premature flower-bud initiation in tomato-seedlings caused by 2,3,5-triiodobenzoic acid. Proc. Akad Wetensch. Amsterdam *51*: 248-251.

YASUDA, S. 1940. A preliminary note on the artificial parthenogenesis induced by application of growth promoting substance. Bot. Mag. Tokyo *54*: 506-510.

ZAITZEV, S. C. 1922. A hybrid between Asiatic and American cotton plants, *Gossypium herbaceum L.* and *G. hirsutum L.* var. *laciniata.* Bull. Appl. Bot. Plt. Breeding *13*: 117-134.

ZIMMERMAN, P. W. and HITCHCOCK, A. E. 1942. Substituted phenoxy and benzoic acid growth substances and the relation of structure to physiological activity. Contrib. Boyce Thompson Inst. *12*: 491-496.

————1949. Triiodobenzoic acid influences flower formation of tomatoes. Contrib. Boyce Thompson Inst. *15*s 353-361.

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SECTION OF ZOOLOGY AND ENTOMOLOGY

PRESIDENT:—B. C. BASU, D. Sc., F.E.S.I.,

Presidential Addresses

The evolution of Applied Entomology in India and its future.

"By mutual confidence and mutual aid
Great deeds are done and great discoveries made"

Ladies and gentlemen,

My first duty is to thank you and the members of the Indian Science Congress Association for the very great honour which you have done me by asking me to preside at the present meeting of the Section, an honour which I most deeply appreciate, not so much on personal grounds, as on behalf of the Indian Veterinary Research Institute. The Indian Science Congress is the only opportunity which the scientific workers of all branches in India have annually of meeting together and exchanging their ideas; as such it is essentially the most important stimulus to scientific research work in this country.

It took me quite a long time to decide what subject to choose for this address. For the past 23 years my work has centred mostly on problems of transmission of diseases of men and animals through arthopod vectors a branch of Applied Entomology and what has impressed me more and more in the study of this subject is the large and important part which workers in India have played in the development of this branch of science. I have therefore chosen the evolution of Applied Entomology in India as the subject of my address for there are many lessons from the past for the workers of the present and the future.

I have divided the subject in eight branches namely *Agricultural Entomology, Plant Protection and Quarantine Organisation, Forest Entomology, Medical Entomology, Veterinary Entomology, Entomology and lac cultivation, Entomology and Silk industry, and Bee-keeping and honey,* and have tried to briefly trace the development of each branch in India.

Before starting the actual subject matter, I would express my thanks to Dr. S. Datta, Director, I. V. R. I. for his help in various ways and to Dr. H. S. Pruthi, Plant Protection Adviser with the Govt. of India, Dr. P. K. Bose, Director, Lac Research Institute, Dr. N. C. Chatterji, Forest Entomologist, I. F. R. I., Dr. D. P. Rai Chaudhury, Deputy Director, Sericulture, West Bengal and Mr. R. N. Muttoo, Honorary Deputy Director of Agriculture, U. P. for their help in way of supplying me with material for this address.

AGRICULTURAL ENTOMOLOGY IN INDIA

Agricultural Entomology in India owes its origin to Wood Mason of the Indian Museum. Till the close of the 19th century all research and information on Indian insect pests were within the field of activities of the Indian Museum (Zoological Survey of India). Wood Mason (1884-85) carried out investigations on the Tea bug and Tea mite of Assam and on *Paraponyx oxyzalis*—a pest of rice in Burma. In 1888 Cotes carried out investigation on the wheat and rice weevils of India. Increased demand for information on crop pests of India necessitated the creation of the post of Entomologist to the Government of India and Lionel de Niceville was appointed to the post in January 1901 with headquarters at the Indian Museum. He actually started field study of crop pests. He studied the Mosquito Blight of Tea at Darjeeling where he died of fever in 1901. E. P. Stebbing carried out the Entomological work at the Indian Museum for some time. Till 1903, six volumes of Indian Museum notes on Economic Entomology were published from the Indian Museum.

H. Maxwell Lefroy succeeded de Niceville as entomologist to the Government of India in 1903. He started with the study of cotton pest of Surat. In 1905 when the Central Agricultural Research Institute was started at Pusa, Lefroy was transferred there as Imperial Entomologist to the Government of India. He studied the life histories of insects and. devised control measures against insect pests. He built up a very useful collection of insect specimens. His valuable publications, namely, "Indian Insect Pests" (1906) and "Indian Insect Life" (1909) show his power of pen, energy and hard work. Lefroy left India in 1912. He visited India again in 1915-16 and wrote a comprehensive report on sericulture.

T. Bainbriggs Fletcher took up the place of Lefroy as Imperial Entomologist to the Government of India in 1913 and held that post till 1932. During Fletcher's time Insect Taxonomy received the greatest attention at Pusa. He built up a splendid library and a valuable collection, particularly of the order Lepidoptera. A number of valuable memoirs on agricultural insects were published by him and his colleagues during his period of service.

Hem Singh Pruthi took up the place of Fletcher as Imperial Entomologist to the Government of India in 1934 and held charge of that post till 1946 though for the last few years he served as Director, Imperial Agricultural Research Institute. In 1946 Pruthi left Imperial Agricultural Research Institute to take up the post of Plant Protection Adviser with the Government of India. His field of work on plant protection organisation has been shown in another chapter. During Pruthi's time considerable amount of research work on several serious pests of Indian crops had been conducted. They are Boll worms of cotton, Borers and Hoppers of sugarcane, pests of fruit, locusts, stored grain pests, tea mites etc. A large number of memoirs on insects of agricultural importance were published by Pruthi and his colleagues. Pruthi left an extensive scheme for expansion of the Division of Entomology at the Indian Agricultural Research Institute. Aiyer is acting in place of Pruthi as Head of the Division of Agricultural Entomology at the Central Institute.

Mention may be made of Howlett, Mason, Isaac, Misra, Ghosh, Dutt, Naoroji, Pradhan, Bose, Mukerjee, Lal, Samuel etc., as other workers of importance on Agricultural Entomology at the Central Institute.

Agricultural Entomology had extensive development in Provinces and States. Eminent Entomologists like Husain, Richard, Rao, Ayyar, Lal and Sen developed Agricultural Entomology in Provinces.

Importance of Agricultural Entomology.

India's average annual production of food grain is about 67 million tons but only 40 per cent of it reach the market for sale. This reduction is due to insects and rodents which cause this enormous damage. Besides damage to food grains there is enormous annual loss due to insects in the yield of sugarcane, potato, tobacco, cotton, jute and various kinds of fruits.

Agricultural Entomology at the Centre as well as in the Province plays important role in the reduction of this huge loss to the country. In this connection special mention may be made on the work of the Central Agricultural Research Institute on the biological control of the stem and root-borer of sugarcane by means of mass liberation of egg parasite—*Trichograma evanescens minutum* in the field. *Trichograma* parasites are being artificially bred in millions at the laboratory and are being utilised in large scale at a low cost of Rs. 1—12—0 for treatment of sugarcane crop per acre for one season. They have started a similar work on the control of potato tuber moth—*Gnorimoschema operculella* by an exotic larval parasite—*Bracon* (*Microbracon*) *gelechiae* imported recently from Canada. Their work on locust control is well-known.

THE PLANT PROTECTION AND QUARTINE ORGANISATION IN INDIA

To Hem Singh Pruthi, Plant Protection Adviser with the Government of India goes the credit of organising the establishment of this important branch of science in India. As is well-known, our country has been suffering from a more or less chronic food deficit ever since the last great war commenced and the latest position seems to be that the deficit is of the size of about four million tons, which has to be met immediately by an importation of food grains from abroad at enormous cost. The Government of India in the Ministry of Agriculture have been endeavouring to remedy the situation by adopting various methods of stepping up food production in the country under the "Grow More Food" Campaign by extending the area of cultivation, by providing more water, better manure and better seed. However, it should be recognised that a leaky tank never fills. Whatever the increase in crop production may be, India is subject to the incidence of various pests and diseases of crops which, on the average, bring about, in a normal year, a reduction of 10 per cent of the yields, and in some years, when they happen to appear in an epidemic form, the losses may amount to over 50 per cent. In 1943, the *Helminthosporium* disease of paddy was the major factor in causing the disastrous famine in Bengal. In 1946-47, the wheat rust epidemic caused a loss of about two million tons of wheat. The devastation that locust infestations can cause is too well-known to be specially mentioned. It has been estimated that India normally suffers, as a result of damage caused by all manner of animal pests and plant diseases to growing crops and stored grain, a total loss of about 500 crores of rupees. This includes roughly about five million tons of cereals and other food crops, and if this loss can be prevented by plant protection methods, we may expect to be well on the way to wipe out our food deficit. It was, in view of these circumstances that the Indian Famine Commission and the Food and Agricultural Organisation of the United Nations laid special stress on the importance of plant protection as being the most important single factor in stepping up food production.

Not only has this country to check pests and diseases indigenous to it, but it has also to safeguard itself against the entry of those of foreign origin, for our experience shows that some of our most harmful pests and diseases are those introduced from outside. We have, therefore, to beware of allowing foreign forms of pests and diseases of plants entering the country and complicating an already difficult situation in respect of food production. It was with a view to safe-guard the interests of the country in these respects that the Government of India established about 2 years ago an organization (now called the Directorate of Plant Protection, Quarantine and Storage) on a permanent besis, which was designed to become fully equipped, in the course of 5 years, to undertake the following functions:

1. Responsibility for the control of pests and diseases of all-India or multi-provincial importance such as locusts, army worms, smuts rusts, etc.,
2. Assisting the provinces and states in putting up plant protection organizations and undertaking province-wide campaigns against their major pests and diseases,
3. Preventing the entry of dangerous pests and diseases from foreign countries by air, sea or land,
4. Preventing the spread of regional pests and diseases from province to province, and
5. Serving as a bureau of information in regard to insect pests and diseases, parasites and predators of pests, and various noxious animals and plants.

Work to the credit of the Organisation.

1. *Locust control.* Locuct infestations in north-west India are generally found appearing in cycles. The last cycle occurred during the years 1940-1945, and the previous one during the period 1926-1931. Although the intensity of the outbreak and the density of swarms were more or less equal in both these cycles, in 1926-1931, the control measures were carried out independently by the affected provinces and states without reference to the distribution of infestation in the country as a whole, with the result that certain sparcely inhabited areas in the Rajputana desert where intense breeding generally occurs were left uncontrolled. On the other hand, during the last cycle, the Government of India had a Central Locust Control Organization which studied the infestation in the country as a whole and judiciously co-ordinated the control work in the provinces and states with the result that the outbreak was fully and efficiently controlled. During the 1926-1931 outbreak, the official estimate in regard to the losses caused by locusts in various ways (by damage to crops and pastures) and its affect on live-stock, and by expenditure on famine relief etc.) was about Rs. 7 crores. During the cycle of 1940-45, the total cost of the control measures taken by the Centre and the affected provinces and states amounted to Rs. 25 lakhs, but the damage to crops was found to be more or less neglible in view of the efficieny of control, so that the cost of control worked out at about a little over 3 per cent of the total losses that the country might otherwise have suffered on the basis of the 1926-31 data,

Whereas in the African and Arabian areas, locust infestation continued till 1948, it had practically disappeared in India by the close of 1945. It may be mentioned here that the Plant protection Directorate is a logical outcome of, and in fact, actually an expansion of the work of Locust Control Organisation, which is now a part of it.

2. *Plant Protection Work in the Provinces and States.*

Though the ultimate object of the Entomological and Mycological Sections of Agricultural Departments in provinces and states, wherever they are in existence, is the devising of practical remedial measures for various pests and diseases of crops for the benefit of the cultivators, the staff provided have usually been so limited or have other duties to attend to such as research and teaching, that it has not been possible for them to undertake control work on a large scale—and without work on a large scale, it is plain that very little impression can be made in respect of making up the general food deficit of the country.

One of the first steps taken by the Central Plant Protection Organization was the preparation of a model plant protection scheme fitted for adoption by an average province, and its circulation to various provinces recommending an immediate starting of plant protection work. The plant Protection Adviser and his Deputy Directors subsequently visited most of the provinces and after discussion with the Agricultural Officers helped them to formulate schemes suited to the conditions of various provinces.

As a result U.P., Bombay and Madras have established full fledged plant protection organisations suited to their conditions and in many other provinces fairly large plant protection schemes are under consideration. Among the states, Mysore has recently set up a good organization designed to serve the whole state. In Ajmer, Coorg and Delhi, scheme of plant protection in respect of seed-dressing of cereals, control of hairy caterpillars and grasshoppers, spraying of orchards, etc., have been in progress.

In Bombay, a campaign against the Rice grasshopper on a large scale last year in Belgaum district by dusting B.H.C. (Gammexane and Hexyclan) had the effect of saving, on the whole, a quantity of 1,98,000 mds. of paddy estimated to cost Rs. 22 lakhs over an area of 22,000 acres, which would have otherwise been lost by grasshopper damage. Over one lakh acres of jowar were found being attacked by the Decan grasshopper pest in the districts of Belgaum, Dharwar and Bijapur, but control work could not be undertaken except on a small scale in view of the lack of availability of Dusting Machines in sufficient numbers.

In Coorg, over 4,000 acres of citrus orchards were sprayed this year against leaf and fruitful resulting in greatly increased yields of fruits, and if it had not been for a want of sufficient spraying equipment, much larger area could have been protected.

In view of the fact that most of the pesticides and spraying and dusting equipment have had to be obtained from abroad, the Government of India have recently sanctioned a Central pool of spraying and dusting equipment and insecticides, so as to be readily available for transfer or loan to such of the provinces or states as may be in urgent need of them.

3. *Quarantine work.*

Several of the serious insect pests and diseases with which India is afflicted are of foreign origin. They got entrance into the country along with plant imports in the course of normal commerce. Coming under this category are the San Jose Scale of apple, the Fluted Scale of Orange, the Woolly aphis of apple, the Potato Borer, the Coffee Rust, the Tea Blister Blight and the Flag Smut of wheat; and among some of the well-known imported noxious weeds are the water Hyacinth, Lantana and Prickly Pear.

India is fortunately free at present from various other dangerous pests and ailments of crops found in foreign countries; as for example, the American Cotton Boll Weevil, the Colorado Beetle, the Wheat Stemfly Codling moth of apple, the Potato Wart disease, the South American Rubber disease, the Tobacco Caterpilar etc. As it is important to tighten the legislative cordon to keep them out of India in the interests of the country's economy arrangements are in progress to establish up-to-date fumigation stations at the main points of entry into India by sea, air and land.

As some of the diseases and pests are yet confined to particular parts of India, arrangements are under foot to prevent their spread into other provinces or states. As an instance of this kind of effort, may be mentioned the measures taken against the spread of the Fluted Scale (*Icerya purchasi*). This insect was introduced accidentally into Madras from either Ceylon or Australia along with imported plants, and was found to have developed by 1928 into a serious pest of Wattles on the Nilgiris. As the result of an importation of its natural enemy—a ladybird beetle—from California, the Madras Government successfully checked its activities on the Nilgiris by 1930. As a result of the financial crisis of 1931, that Government discontinued work on its control, on the presumption that no further attention was necessary. After about 11 years, however, it was found that the pest had not only re-appeared on the Nilgiris, but had spread to the Pulney Hills, and into Travancore, Mysore, and Coorg and had reached as far north as Poona, with the result that the Central Government as well as the Provincial and State Governments have been obliged to take control operations against it since 1946 at considerable annual expenditure. As this insect is konwn to be a very serious pest of Citrus and other fruits in California and Florida in U.S.A., it has become necessary to prevent it from reaching the citrus areas of Central Provinces, Coorg, etc.,—a work which is one of the responsibilities of the Central Government. It may be stated that, at present, the pest has been controlled to a very great extent in Madras, Travancore and Mysore, and that Coorg and Bombay are now practically free.

FOREST ENTOMOLOGY IN INDIA

To B. Ribbentrop, Inspector General of Forests, is due the credit of demonstrating the need of a Forest Entomologist. The post was sanctioned for two years and E. P. Stebbing, was appointed to the post at the end of 1900. Stebbing was prolific with his pen, and 'Departmental notes on insects that effect Forestry' began to appear from 1902 and continued till 1906. He also published popular articles in the *Indian Forester* and the

Journal of Bombay Natural History Society which ran in serial parts from 1901 to 1908. But in spite of the efforts of R. C. Wroughton, Inspector General of Forests, to obtain the prolongation of the post, it was dropped for the time being and Stebbing took the officiating post of the Superintendent of the Indian Museum early in 1903.

As a result of representation of Eardley Wilmot, Inspector General, the Imperial Forest Research Institute was established in 1906 by raising the status of Forest School at Dehra Dun and creating 6 research posts. Stebbing was appointed Imperial Forest Zoologist in April 1906 and held the office until December 1909. The post was renamed Forest Entomologist in 1922. During this period Stebbing made important preliminary surveys of the insect fauna of Sal, (*Shorea robusta*) and the conifers and contributed abundantly in the departmental publications. In 1907 he completed 'A Manual of Elementary Forest Zoology for India'. He left India in December 1909 and after his departure published in 1914 "Indian Forest Insects of Economic importance."

In December 1909 V. Subramaniya Iyer, was appointed temporary Forest Zoologist and held the post till April 1911. In October 1911, A. D. Imms was appointed Forest Zoologist and within his short term of office of 16 months, he did valuable research work and laid the formation of an authentically identified insect collection, a good library, and adequate laboratory equipment. He made contacts with entomological specialists in many countries and large collections were distributed to them. Imms' association with forest entomology at a time when a new institution was projected and funds for the expansion of entomological research had to be secured, was a most fortunate occurrence.

In August 1913, C. F. C. Beeson, was transferred from the Punjab to take over the post of Forest Zoologist. During Beeson's terms of office forest entomology made immense progress. Many insect pests of forest trees were studies and control measures devised. Particular attention was paid to the ecology of forest insect pests. The heartwood borer of sal (*Shorea robusta*), the root borer of babul (*Acacia arabica*) and various others were studied. Biological control of defoliators of teak, shisham, mulberry, deodar, and lantana and others were taken up as a special line of investigation. The insect pests of millyards, wood working industries and ordnance factories were studied and N. C. Chatterjee took up an intensive survey of the fauna of sandal tree in connection with the spike disease of sandal. Beeson published several papers on forest entomology and his last was "The ecology and control of the forest insects of India". Beeson retired in 1941 and the post of forest entomologist was taken over by J. C. M. Gardener, Systematic Entomologist at the Institute. During Gardener's term of office work was concentrated on the protection of bamboo a war problem. Gardener retired in May 1947 when A. H. Khan, took over. Chatterjee's work at the Institute since 1911 in economic entomology comprise—lac insect, sal, babul and other borers, toon fruit and shoot borer, bamboo borers, defoliators of teak, sal, gmelina, casuarina and others, champ bug, spike disease of sandal, biological control of lantana, termite control and insecticides.

The pest of the timber trade and wood using industries, as also the borers and termites that concern the Public works, Railways and Army departments have in practice formed major subject of research at Dehra

Dun and must continue to do so. The fundamental methods of control have been worked out but the new problems arising from the increasing industrialisation of India will always need special attention.

Undoubtedly more forest capital is destroyed by pests, diseases and fire than is utilised. The following examples illustrate the variation in value and extent of damage caused by some of the major pests of Indian Forestry.

1. *Hoplocerambyx spinicornis.*—the sal heartwood brorer: The recurrent annual damage has been estimated at Rs. 2½ lakhs on sal timber extracted from state forests alone; or an annual loss of 2 annas per acre on the outturn of a million acres in the United Provinces alone. During epidemics the loss rises to an average of Rs. 18|- per acre. In the peak year of the calamity which affected five forest divisions in Central Provinces, Rewa State, and much private land, the loss of forest capital was over 137 lakhs of rupees.

2. *Hypsipyla robusta* and *Pagiophloeus, longiclaris* both borers of *Cedrela toona* and *Swietenia macrophylla.* Where young plantations of these species have been written off because of borer attack, the expenditure wasted is between Rs. 15|- to Rs. 30|- per acre.

3. *Hapalia machaeralis* and *Hybloea puera,* the teak defoliators: The severest epidemics of teak defoliators cause a loss of Rs. 130- per acre in fully stocked first quality teak plantations with a royalty of Rs. 2|- per cubic feet. In such crops the normal annual defoliation is estimated at Rs. 20—25 per acre per annum. In IV or V quality teak forest with a royalty of 8 annas per cubic foot, the loss may be within 2 rupees per acre per annum.

4. *Plecoptera reflexa,* the shisham defoliator: In some of the irrigated shisham plantation this defoliator has completely frustrated attempts to grow a pure crop of shisham and failure has incurred losses of Rs. 20|- to Rs. 40'- per acre. In established crops the annual yield over 46,500 acres is reduced by a third to a half.

5. *Calopepla leayana,* the defoliator of *Gmelina arborea,* was one of the chief factors causing the abandonment of plantations in Burma, Bengal, Assam, having a capital value of over 4½ lakhs of rupees *i.e.,* a loss of Rs. 280|- per acre.

6. Spike disease of sandal, which is a virus disease transmitted by insects has caused a loss of nearly 500 lakhs of rupees in Coorg, Mysore, Madras during the last 50 years and about 10 lakhs a year now-a-days.

These illustrations should suffice to show that losses due to insect pests may be small and possibly tolerable in poor types of forests but they increase as the productivity of the forests is increased and will become more so in future.

The total expenditure on the entomological branch of the Forest Research Institute during the past 40 years is about Rs. 21,00,000. This covers research in India up to date and in Burma up to about 1928. To assess the net cost of research, one should deduct from this total the salaries of staff employed part time on educational work in the Forest Colleges and the material assets, *viz.,* the entomological collection of some 17500 species, the library, two museums which together have a very high permanent value.

If this balance is regarded as an investment, on which one might expect a return of 10 per cent compound interest plus the original capital, it will be evident that the whole amount involved is less than the loss that can be caused by a single major epidemic of the Sal-Borer. It is claimed that at least one such epidemic has been prevented and controlled by knowing how to prevent it. It is concluded that the total outlay on research has thereby been recouped. All the additional knowledge gained about the control of hundreds of other pests of forests and forest products can be regarded from the financial view point as net profit available for financing future research.

MEDICAL ENTOMOLOGY IN INDIA

The development of Medical Entomology in India has a brilliant record. Formerly insects were regarded merely as causing annoyance or direct injury to man and to his livestock and crop. But at the last decade of the nineteenth century it was found out that they are responsible for transmission of a number of serious diseases of man and animal. The recognition of this fact revolutionised the methods of control of those (insect-borne) diseases. The modern methods of treatment of tropical diseases trend more and more towards the control of insect vectors as 'Prevention is better than cure'. Manson's (1878) discovery of the transmission of *Wuchereria bancrofti*—the causal organism of filariasis of man—by *Culex fatigans* at China opened the chapter of Medical Entomology. Sir David and Lady Bruce's discovery of Nagana has been referred to in connection with Veterinary Entomology. Then came the epoch-making discovery of Ross (1898) on the role of mosquitoes in the transmission of malaria. Due to the discovery of Ross in India, the importance of malaria to India and coincidentally the availability in India of a group of eminent workers that followed Ross, a large amount of solid work was done on Medical Entomology, particularly, on mosquitoes. Immediately after the discovery of Ross, a Commission to investigate the Malaria Problem was appointed and Daniel was the first member of the Commission to arrive in India in December 1898 to substantiate the findings of Ross. Stephens and Christophers other members of the Commission arrived in India in 1901 to start their Entomological investigations, and within a few years substantial work on mosquitoes were produced by Stephens, Christophers, James and Liston— all belonging to the Indian Medical Service.

In 1909, the Imperial Malaria Conference, recommended the creation of a Central Scientific Committee to carry out routine work on the distribution and bionomics of the different species of *Anopheles*. In 1910, the Central Malaria Bureau was started to carry out research work on mosquitoes and malaria. In 1911, the Indian Research Fund Association was organized with the grants from the Government of India to supervise and finance research enquiries into various human diseases and also on various important entomological subjects connected with them, namely problems on transmission and eradication of malaria, Kalaazar, Oriental sore, relapsing fever, plague, filariasis, guinea worm etc., and the works were mostly conducted at the Central Research Institute, Kasauli, Malaria Institute of India, Kasauli and Delhi, School of Tropical Medicine, Calcutta and King Institute of Preventive Medicine, Guindy. There is a long list of names of persons who conducted investigations on various enquiries on Medical Entomology in India under the auspices of the Indian Research Fund Association. They are James, Christophers, Liston, Patton, Cragg, Sinton, Covell, Shortt, Turkhud, Awati, Senior White, Barraud, Puri, Smith, Swaminath, Mehta, Mukerjee, **Basu etc.**

In 1922, Strickland was appointed as the first Professor of Medical Entomology at the Calcutta School of Tropical Medicine and served for a long period of nearly two decades. Roy acted in his place till his retirement.

In some of the provinces, also medical Entomology had considerable development on the Public Health side. Special mention should be made of the valuable work of Iyengar in this connection.

Arthropod Transmission of Human diseases .

The insect transmission of malaria,plague, relapsing fever, Kala-azar and guinea-worms have all been discovered by investigators in India and that is a glorious record of which any country may be proud.

In 1898, Ross discovered in India the transmission cycle of bird malaria in Culex mosquitoes and stated that a similar cycle would apply in the transmission of human malaria through the agency of Anopheline mosquitoes. In the same year Grassi in Rome demonstrated the transmission of human malaria by *Anapheles maculipennis* and experimentally infected a volunteer by mosquito bite. In India, there is a lengthy record of series of experiments on the infectivity of different species of Anophelines with malaria. In this connection special mention should be made of the works of Stephens, Christophers, James, Liston, Sinton, Bentley, Iyenger and others. Knowles and Basu (1943) and Basu (1943) carried out extensive investigations at the Calcutta School of Tropical Medicine with a grant from the Indian Reasearch Fund Association to determine for the different transmitting species of Indian Anopheles what are the limits of atmospheric temperature and relative humidity between which transmission of malaria will take place. The work started with the hope that if it can be shown that transmission is only possible between certain limits of atmospheric temperature and humidity all anti-malaria and anti-mosquito measures could be concerntrated into such periods that are climatically suiable and there would be an immense saving of labour and material in connection with malaria control; also once the limits are known the anti-mosquito campaign could be carried out with very much greater efficiency. The results were published in 1943. Chopra and Basu (1937, 1938, 1939) worked out the effect of various anti-malarial drugs upon the infectivity of patients to susceptible mosquitoes. The problem of transmission of Kalaazar from man to man had been one of the outstanding puzzles in tropical medicine for nearly a quarter of a century. In 1924, Knowles, Napier and Smith at the Calcutta School of Tropical medicine first reported the development of the flagellate stage of *Lieshmania donovani* - the causal organism of Kalazar in *Phlebotomus argentipes* the 'silver footed sandfly'. Christophers, Short, Smith and Swaminath working in Assam finally proved that Ph. *argentipes* is the transmitting vector of Kalaazar. In 1907. Mackie working in Bombay found out that Asiatic relapsing fever is transmitted by body louse—*Pediculus.*

Simond in 1898 first succeeded in transmitting plague from rat to rat through the agency of flea. However, it was not till 1904 when Liston working in Bombay finally succeeded in flea transmission of plague.

Turkhud, in India, proved that a man who ingested cyclops infected with *Dracunculus medicinensis* (guinea worm) embryos showed the worms after an incubation period of 348 days.

Sunder Rao and Iyengar (1932) exprimentally found out that besides *Culex fatigans,* a number of Indian species of Anopheline and Culicine are efficient vectors of human filariasis. Basu and Sunder Rao (1939) at the Calcutta School of Tropical Medicine worked out the various factors involved in the mosquito transmission of filariasis in man.

Chopra, Basu and Sen (1939) and Basu and Sen (1945) at the Calcutta School of Tropical Medicine made a thorough investigation on rat bite fever due to *Spirillum minus* and studied its probable arthropod transmission.

The record is so voluminous on the subject of Arthopods in relation to human diseases that it may take pages to summarise it.

Survey of insects of medical importance.

There are many reports on mosquito surveys of India, most of them being buried amongst office files of the Public Health Departments of various provinces; Sinton took enormous troubles to catalogue them all. Covell published a memoir on the distribution of Anophilines in India. Anophiline and culicine mosquitoes have been mapped. Fleas, flies, human lice and sand flies have also been mapped.

Control of insects

Control of insects by various insecticides as well as by Biological control has been tried all over the country mostly from the provincial Public Health Departments. Special mention may be made of mosquito control work of Delhi, Bombay and Calcutta and certain rural areas of Bengal and flea control work of Bombay.

Recently World Health Organization have started an experiment at Gokulnagar in U.P. to test the possibility of controlling malaria by spraying DDT once in a year. If it succeeds it will be a great service to humanity.

Systematic Medical Entomology

In 1913 Patton and Cragg published their comprehensive Text Book on Medical Entomology. Brunetti's work has been mentioned in connection Veterinary Entomology. Christophers, in 1933, published a volume on Anopheline in the Fauna of India series and in 1934 Barraud published volume on Megharini and Culicini in the same series. Prashad, Senior White, Iyengar, Puri and others contributed towards the systematic side of Anopheline. Sinton published a series of articles on the systematics of Phebotomus flies of India. Puri worked on the systematics of the Simulium flies of India. Mukherjee worked on the systematics of culicoides of India. Shariff made contribution on the systematics of Fleas and hard ticks of India.

Medical Entomology and its importance

Insects are reponsible for a human mortality of over one and a half millions a year in India. No pen can write its money value. *

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* (To quote Mackie, once His Majesty the King of England said "We speak of Preventable disease, but if preventable why not prevented". Will our free country echo it?).

VETERINARY ENTOMOLOGY IN INDIA

Veterinary Entomology in general is of recent origin. In fact it had its birth with the great discovery of Theobald Smith and F. L. Kilborne, of the Public Health Service U.S.A., who in 1893, proved beyond doubt the transmission of *Babesia bigemina,* the causal organism of the Texas Cattle fever from animal to animal through the agency of *Boophilus annulatus*—the common cattle tick. This, however, did not attract the attention it merited. Two years later in 1895, Sir David and Lady Bruce, working in Zululand under conditions of incredible hardship discovered the transmission of *Trypanosoma brucei*—the causal organism of Nagana by *Glossina morsitans*—the tsetse fly, and also worked out the transmission cycle of the causal agent of the disease. This was a discovery of enormour importance and it paved the way for a number of subsequent discoveries in this field. In 1903, Marchoux and Salimbeni proved that fowl spirochaetosis is a tick-borne disease and that the common fowl tick (*Argas pericus*) is responsible for its transmission. Subsequently a number of such discoveries came up from various countries.

In the absence of any organisation for dealing with problems of Veterinary Entomology in India, work of exploratory nature had been largely incidental to other activities of the Veterinary Department and also to those of the Medical and Agriculture Departments and the Zoological Survey of India. In 1907, Howlett joined the Indian Agricultural Research Institute as Second Imperial Entomologist and in 1912 his designation was changed as Imperial Pathological Entomologist. Isaac took up the place of Howlett in 1922. Howlett and Isaac studied the order Diptera, including those that are parasitic on domestic animals.

In 1919, Howlett worked out a scheme for the creation of a separate organization to deal exlusively with the problems of Medical and Veterinary Entomology in this country. This organisation was to consist of 10 officers and 46 assistants. The first meeting of the Veterinary Officers held at Lahore in 1917 considered and accepted the proposal. As nothing happened till 1923 the same question came up again in the second meeting of the Veterinary Officers held in 1923 and the following resolution was passed. "On account of the great importance of insects in the transmission of animal disease, as causes of direct injury to live-stock in India and the degree of specialization necessary for the proper appreciation of the various aspects of entomology, the staff of the Imperial Entomologist should be strengthened to the degree requisite for rendering assistance to investigators into the insect problems connected with animal diseases. Similarly facilities should be rendered for the establishment of a staff attached either to the Imperial Entomologist or to the Zoological Survey of India for the study of ticks and mites concerned with animal diseases". This led to the creation of a post of an Entomologist at the Imperial Veterinary Research Institute at 1933 and S. K. Sen was appointed to it. Sen's place was taken by B. C. Basu in September 1941 as Entomologist, Indian Veterinary Reasearch Institute. Basu joined Indian Vetenary Research Institute in June 1939 as Assistant Entomologist. Basu's place was taken by B. N. Soni as Assistant Entomologist.

Indian Council of Agricultural Research financed a number of schemes on various aspects of Veterinary Entomology, such as, ox Warble fly, tick etc.

Transmission of animal diseases.

The study of the transmission of diseases of animals through the agency of arthopods has been one of the main items of investigation on Veterinary Entomology at the Indian Veterinary Reasearch Institute. Important diseases studied so far form this point of view are, Surra, rinderpest, anthrax, haemorrhagic septicaemia, theileriasis, fowl spirochaetosis and hump sore.

The attention of the Veterinary Officers in India was early drawn on the question of Transmission of *Trypanosoma evansi* - the causal organism of Surra - a fatal disease of horse, camel and mule and a chronic disease of cattle. This was the start of Veterinary Entomology in India. Rogers (1901) was the first person to test the possibility of *Tabanus* flies involved in the transmission of surra. Subsequent workers on the same problem were Baldrey (1911), Cross and Patel (1921-22), Kahan Singh (1925-26), Sen (1938) and Basu (1947). Basu at the Indian Veterinary Research Institute confirmed the Tabanus transmission of surra and proved experimental transmission of surra by *Haematopinus tuberculatus* and *Musca* (mostly *nebulo*).

Christophers (1907) and Shortt (1937), both while in Indian Medical Service, worked out the transmission of *Babesia canis* and *Pattonella gibsoni* -casual organisms of canine tick fever through the agency of *Rhipicephalus sanguneous* and *Haemaphysalis bispinosa* respectively.

Basu (1930) transmitted *Pasteurella avicida*—the causal organism of chicken cholera through the agency of *Argas pericus*. In a memoir, Knowles Das Gupta and Basu (1932) gave a through account of the mechanism of tick transmission of *Spirochaeta anserina*—the casual organism of fowl Spirochætosis and the life history of the parasite in *Argas pericus*. In a memoir, Knowles and Basu (1935) worked out the tick transmission of *Spirochaeta cobayae*—the casual organism of relapsing fever of guinea pigs, the casual organisms being first described by the same authors.

Mehra (1941) showed that healthy rabbits contracted haemorrhagic septicaemia through *Ctenocephalis felis*.

Sen and Minett (1945) succeeded to transmit antharx through *Musca domestica*. Basu (1948) transmitted anthrax through *Musca nebulo, Ctenocephalis felis* and *Hyalomma aegyptium*.

Sen (1926), Bhatia (1935), Kapur (1941) and Basu (1947) studied the possibility of arthopod transmission of rinderpest. Bhatia and Kapur succeeded to transmit the diseases through *Tabanus orientis* and Basu succeeded to transmit the disease through *Stomoxys calcitrans* after a period of incubation of the flies at a temperature of 22°C.

Survey of insect and acarid vectors of livestock in India.

Information concerning the distribution of arthopod vectors of many important diseases of livestock is being obtained with a view to control diseases in a particular locality in this country. Surveys carried out by the Entomological staff at Indian Veterinary Research Institute and the Veterinary investigation Officers have resulted in the finding that several important pests of livesstock are distributed over a much wider area in India than had been previously believed to be the case. *Hypoderma lineatum* and *H. crossi*—ox and goat warble flies respectively and various species of cattle ticks and Tabanid flies of India have been mapped. A few interesting findings in this direction may be mentioned here. *Hunterellus hookeri*—the tick parasite occurs in Dharwar in the province of Bombay; *Ornithodorus megnini*—the spinose ear tick has been recorded from Saugor, Mhow and Ahmednagar; *Cytoleichus nudus*—the Air Sac mite in fowls was reported from Mukteswar. The list would be of considerable size if all such names are included.

Control of insects and ticks.

Control of arthropods by insecticides, such as, D.D.T., Benzene hexachloride, Derris powder, Tobacco-lime mixture, Pyrethrum and several other preparations and by Biological methods has been under study for the past several years at the Indian Veterinary Research Institute. In the control of warble-fly successful results were obtained in the field in the Punjab by periodically singeing the hairs on legs of cattle during warble-fly season. Considerable amount of work has been done in the control of ectoparasites of cattle, sheep, goat and poultry.

Special efforts are being made at the Indian Veterinary Research Institute to artificially breed *Hunterellus hookri* on a large scale with a view to eradicate completely susceptible ticks from this country.

Bionomics, life-history and anatomical studies.

Bionomics and life-history of a number of ticks, warble-flies and other arthropods of Veterinary importance have been worked out under Indian conditions at the Indian Veterinary Research Institute as well as in other laboratories.

Machanism of feeding ticks was studied and a structure was discovered in them which is a homologue of the hypostome of insects.

Systematic Veterinary Entomology.

Considerable amount of work has been done on this aspect of the subject. Brunettii published three volumes dealing with Diptera in the series of the Fauna of India (1912, 1920 and 1923) besides a large number of articles in the Records of the Indian Museum. Patton and Cragg (1913) published a comprehensive book embodying available information on the arthropod pests of Indian livestock besides their original observations. Senior White published two useful catalogues dealing with culicidae and Tabanidae of the Indian Region. Patton (1937) published a very useful synopsis of the oriental species of *Musca*. Senior White, Aubertin and Smart (1940) published an equally useful volume on the Family *Calliphoridae* in the Fauna of Indian series. Puri (1932-35) published a series of articles on Indian Simulium. Sharif (1924, 1928) made notable contribution on the Indian species of Family Ixodidae and order *Siphonoptera*. Fletcher and Sen are writing a report on Veterinary Entomology in India which when published will be of immense use to workers in the field.

Importance of Veterinary Entomology.

Over 60 per cent of the country's national income was derived from agricultural, livestock and allied pursuits, Of this the cattle industry contributed over 50 per cent roughly Rs. 2000 crores annually. The growth of India's agriculture depend largely on cattle wealth—they are nearly 25 per cent of the world's cattle.

A significant portion of mortality amongst cattle and other livestock in India can be attributed to arthropodal invasion. In live animals, moreover, they inflict a variety of damages; to mention a few of the more important, these are defective growth, decreased vigour, lowered reproductive capacity and reduced production of milk, meat, egg, wool and work.. Considering the country's huge livestock population, these damages are enormous and may cost many crores of rupees annually. Hide and Cess Committee worked out a monatory loss of two crores of rupees annually to India due to damage to hide and skin caused by Warble flies.

ENTOMOLOGY AND LAC CULTIVATION IN INDIA

Lac is the only natural resin of animal-cum-vegetable origin of commercial importance. India preduces more than 90 per cent of the total world production of this important commodity.

The caccid, that produces lac as a protective covering for itself, belongs to the family *Lacifericae* and the genus *Laccifer.* The species, of the genus *Laccifer,* which produces bulk of the lac of commerce is called *Laccifer lacca.*

The lac insect not only produces the resin called lac in its crude form and shellac in its refined form but also yields a red dye at one time called crimson 'lake'.

The use of dye and some uses of resin were known from ages. But in the world at large before the aniline dyes came into market the dye had major importance. The lac dye was considered second best to that obtained from cochineal insect.

The importance of the resin grew towards the later part of the 19th century. In 1886-87 India exported 23,958 maunds of lac dye and 59,049 maunds of lac both put together valued at Rs. 19,62,394 whereas in 1939-40 for 10,27,359 maunds of lac alone India received Rs. 1,91,19,564 but the highest receipts for lac were Rs. 15,71,85,360 for 4,36,626 maunds of lac in 1920 at the close of the first world war.

Realising the importance of lac both as a peace time and war time commodity and the high prices which the consuming industries had to pay after the first world war, the then Government of India deputed H.A.F. Lindsay and C.M. Harlow to report on lac industry with a view to stabilize it. The report was submitted in 1921 and as a result the Indian Lac Research Institute came into existence and began to function from 1925-26.

Lac is found growing, naturally, on a wide range of trees and shrubs in every province and state of present day India and to a small extent in certain parts of Pakistan. But as a subsidiary and cottage industry it is to some extent cultivated in Chotanagpur Division and Santal Parganas of Bihar, States that have merged in Orissa, certain parts of C. P. Madhyabharat and districts adjoining to Bihar in Bengal and U.P. and Assam.

The cultivation of lac in all these districts and collection of naturally growing lac in other parts of India is chiefly in the hands of the poorest and most illeterate and backward classes. The manufacture and export of lac, however, is in the hands of middle class and rich Indian and European firms.

There is some sort of cultivation in the aforesaid districts but it does not receive the attention which it should even though it is a highly paying and less time consuming industry. This is one of the reasons that the annual production of crude lac in India varies between 6 and 17 *lakh* maunds.

The Institute consists of two research departments viz. Chemical and Entomological. Both the departments at first concentrated on cultivation and the problems embraced various aspects of lac cultivation. However, after 1930 the activities of the Chemical department were directed chiefly to industrial uses of lac and Entomological Department continued researches on cultivation side.

In 1936, the Indian Lac Cess Committee, started a small demonstration scheme in Bengal and Bihar. This scheme was expanded, and in 1942, the Provincial Governments of Bengal, Bihar and U.P. agreed to take part in the demonstration of improved methods of cultivation.

In India and outside certain academical aspects of the lac insect and insects associated with lac have been studied from time to time from 18th century and onwards. In India, such studies, were undertaken chiefly at the Forest Research Institute, Dehra Dun, Imperial (Indian) Agricultural Research Institute, Pusa (Delhi) and the Indian Institute of Science, Bangalore.

It is, however. at the Indian Lac Research Institute that the entire problem was and is being studied from the practical point of view.

Studies on the life history and biology of the lac insect have led to building up of a system which enables a cultivator to cut his crop at correct times, and permits management and despatch of broodlac (seed of lac) to distant places involving a journey of as long as 10 days. It may be stated that broodlac is a very costly commodity and highly perishable.

The visual system of forecasting the dates of emergence of lac larvae, evolved by the Institute, ensures vivility in broodlac, maximum possible out-put of lac by each individual female insect and hence production of maximum crops. It may be stated that each healthy female in full life produces very little lac and to produce one pound of *kusumi* lac about 15,655 and 6,580 females are required. Very frequently in the winter season when lac on *Schleichera trijuga* (kusum) trees matures, the temperature falls below the maximum optimum temperature required for emergence of lac larvae and as such the cultivators are not able to grow the succeeding crop. Under such circumstances by adopting the methods evolved by the Institute the cultivation can at least grow and obtain 40 per cent of the normal crop.

Taking all the lac crops into consideration there are about 35 per cent males and 65 per cent females. But it is the females only that produce lac worth collection. The investigations at the Institute have paved the way for producing a brood of female lac insects which asexually might produce only female progeny and thus raise the production of lac by about 20 per cent.

The chief lac hosts in order of their efficiency are *Schleichera trijuga* (kusum), *Zizyphus jujuba* (ber) and *Butea monosperma* syn. *B. frondosa* (palas).

A kusum tree as cultivated by villagers gives one crop every two to three years. The Institute has already developed and is teaching the cultivators methods of pruning which enables them to get a full crop every one and a half year. Further experiments under way promise a crop once a year.

Ber and *palas,* which form chief Rangeeni hosts and which produce about 64 per cent of the Indian lac, are deciduous and remain leafless through the greater part of summer. Hence, they do not normally sustain and carry through sufficient brood lac to maturity through the summer season. Consequently, more than three-fourths of the summer crop from these hosts is cut immature and the trees produce only about 50 per cent of the lac than they would do if they had healthy new foliage during the summer season. This state of affairs lends to frequent crop failures, acute shortage of broad lac and large fluctuations in production of lac from year to year. It is also partly responsible to high fluctuations in prices of lac. The uncertainty of sustained productions and high prices are both undesirable to the interest of the industry. More so, when we are only a raw material producing country and the consuming countries depend for its supply on us.

The Institute by its finding of partial defoliation for *palas* and partial light pruning for *ber* to grow the summer crop has to a great extent solved this difficulty of brood lac. These findings in the case of *palas* enable a cultivator to produce 7 per cent more sticklac and enable him to make a net profit of 66 per cent on brood lac against a loss of 18 per cent under the age old system of cultivation; similarly in *ber,* the cultivator makes a net profit of 29 per cent more than by his inherited methods of cultivation. Thus methods evolved will lead to growing of sustained and ever-profitable quality crops.

There are insects which destroy lac and the lac insects. These are broadly divided into two classes, *viz.,* the predators and the parasites. The predators lodge their attack from outside the predators *Eublernma amabilis* and *Holcocera pulverea* destroy the lac insects as well as the lac, whereas the predator *Chrysopa sps.* destroy only the lac insects. The parasites are practically all chaloids and they attack the lac insect from inside the lac test and destroy only the lac insect and not the lac that it has produced before it falls victim to its parasite.

Both the predators and parasites annually destroy about 50 per cent of our productions of lac, *i.e.,* on the average about five and a half lakh maunds of lac. To reduce this colossal loss the Institute has developed cultural and artificial methods of control, *e.g.,* water-immersion. which can be easily adopted by villagers and when adopted are expected to reduce the damage to lac crops by about 30 per cent.

Further, several indigenous insects of importance to be used as biological control have been found out and life history of some of them studied in the laboratory. One of these insects, *Bracon greeni,* which is an exclusive parasite of *Eublemma amabilis* was tried in the field also and the preliminary data show considerable promise.

It may be pointed out that while the crop is growing on the trees, there is no other control method, other than the biological control, which can be adopted against the enemies of lac insects and hence its importance to check the rise of the enemy insects.

Glover, Gupta, Misra and Negi are important workers on lac insect in India.

ENTOMOLOGY AND SILK INDUSTRY IN INDIA

The commonly called silk is the bye-product of the insects of the Saturnidae and Bombycidae families. Its chemical composition is $C_{15} H_{23} N_5 O_6$. The insects producing silk are broadly classified into two divisions namely (1) mulberry-leaf feeding and (2) Non-mulberry leaf-feeding, in which there are both wild and domesticated varieties. There are about 100 different varieties of domesticated silk worms feeding on mulberry leaf producing silk of different quality and quantity as acclimatised in different countries. These worms are again classified as (1) Univoltine yielding one crop a year, (2) Bivoltine—two crops a year, and (3) multivoltine— 4 to 5 crops a year.

Endi, Tassar and Muga are the varieties of non-mulberry silk, produced by the worms *Attacus ricini* (Eri worm) *Antheraea mylitta* (Tssar worms), and *Antheraea Assama* (Muga worms) which are wild excepting Eri-worms, *Attacus ricini,* which are domesticated and feed on castor leaves (*Ricinous communis*). Tssar worms feed on sal (*Shorea robusta*), Kul (*Zizhyphes Jariuba*), Arjun (*Terminalia arjuna*) while Muga worms feed on Champa leaves (*Michelia obelouga*), Hualu (*Litsaca polyantha*).

Amongst different varieties of silk, mulberry silk is considered to be the best due to its richness in quality, universality of use and amenability to large production and practically it is the only silk with which West Bengal, Mysore and Kashmir are concerned most.

Tssar silk, which is produced in a little quantity in the western parts of Bankura and Birbhum districts, *flourishes* well in Chotanagpur and in parts of Bihar. C.P. and Orissa.

Assam is considered to be the homeland for Muga as also for Endi; but the districts of Mymensingh, Rangpur and Bogra in Eastern Pakistan also grow littlle Endi.

The silk industry existed in all its stages in India from very ancient times; but there is no authentic record when this industry developed from start to full industry. There are reports to show that Indians were well-versed in the manufacture of silk cloth since 6000 years ago. This industry is broadly divisible into two groups (*a*) Production or Sericulture proper and (*b*) Utilisation.

Sericulture is a perfect rural home industry as the main working place is the house and involving no heavy outlay of capital. Amongst all cottage

Industries it is the most important, as it perfectly fits in with the work of the agriculturists as their subsidiary occupation.

The economic value of this industry is enormous as it gives direct or indirect occupation to 2, 70,000 number of people throughout the year. Cultivation of mulberry, the principal food of the worms, is mainly done in bush form in West Bengal over 15,000 acres of lands by the Agriculturists and rearing of worms is mainly done by the inmates of their houses during the recesses when leaves are available. Worms of West Bengal being multivoltine, 4 to 5 crops per annum can be raised profitably. Cocoons, when produced, are sold to the market for production of raw silk.

Silk, the raw material of the textile industry, is produced from cocoons by a process called reeling, which is first stage of utilisation. This branch of the silk industry is both cottage and large-scale industry and gives employment to 25,000 persons in West Bengal.

Utilisation of raw silk by manufacture of fabrics is the second stage of utilisation. This section of the industry is called weaving, which is also cottage and factory industry and gives employment to 5,700 persons. Sufficient capital is required to run these two sections of the industry. Thus the three sections of the industry are entirely interdependent and require much attention and co-ordination for proper functioning of the industry. The expansion of the industry is thus entirely dependent not only upon the quick utilisation of the raw materials produced but rather upon exports to foreign market.

India previously used to export sufficient quantity of raw silk to European countries before monopolisation of the trade by Japan. Her exports reached highest level in the years 1866 and 1874 when the annual export rose to 2,203,000 lbs., but this export industry gradually decresed with increased imports of 25,00,000 lbs., of raw silk valued at Rs. 95,00,000 in 1937-38 as raw silk produced in India is not sufficient to meet the requirements of the country itself. The total quantity of raw silk production in India is estimated at 20,00,000 lbs., to 25,00,000 lbs., against her internal demands of 40,00,000 lbs., per annum as is, indicated in the following table for the year 1937-38.

TABLE

Imports (excluding less exports).	Quantity of raw silk produced and imported in India.
Raw-silk.	25,35,274 lbs.
Spun silk yarn.	15,84,289 „
Silk piece goods.	2,77,01,000 „
Mixed silk goods.	86,52,000 „

In prewar days, Japan and China were principal supplying sources. But as a sequel to various restrictions that were imposed upon silk and other textile fabrics by Japan, as also the SinoJapanese war, imports of raw silk manufactures recorded decline from 25,00,000 lbs., valued at Rs. 95,00,000 in 1937-38 to 22,00,000 lbs., valued at Rs. 62,00,000 in 1938-39.

Imports during the war period recorded decrease in minimum quantity when 44,469 lbs., of raw silk valued at Rs. 2,43,380 were exported to European countries from India in 1941-42 inspite of her deficiency in raw materials. Therefore this industry has the vast scope for development in order to meet the demands within the country itself and also to export to other countries.

The potentiality of India for this industry is very great indeed. The silk industry is sought to be maintained because it represents the high water mark of technical attainment in training, knowledge and skill amongst the textile industries. If this high standard was to die out, effect on the other flourishing sister industries such as wool, cotton etc. would be disastrous. In 1949, Government of Mysore had to arrange to import 1,00,000 lbs., of raw silk from Italy and Japan to rehabilitate the handloom industry of the State. The immense potentiality, which India possesses should be harnessed fully for the development of the silk industry more economically and solidly to return to her past glory. Scheme on the following lines are being taken up in West Bengal for the development of this industry.

(1) Gradual replacement of bush mulberry by tree mulberry. This will cut down 60 per cent of the cultivation cost.

(2) Introduction of F1 race by replacing the indigenous races, which will also reduce the production cost by 50 per cent.

(3) Introduction of improved types of reeling and weaving machineries.

(4) Establishment of a full fledged Sericultural Training Institute for imparting Sericultural Training.

Silk industry reminds one of Pasteur's famous study of Pebrine. In 1885, the sericultural industry of the world was faced with ruin; the silk fields of France were mortally stricken with pebrine and even imported seed could not save them, for the infection had spread to Italy, Spain, Austria, Greece and even China. All stages of silk worm were infected. Appeal came to Pasteur who was so distressed by the sufferings of the peasants in the South of France that he immediately took up the problem though Pasteur was no Protozoologist and *Nosema bombycis* that causes pebrine is a protozoal parasite. Pasteur worked out a simple prophylactic measure against the disease. His plan was to crush a few insects from the batch in a little water and to examine under microscope for the refractile pebrine spores. If they were present those worms should not be kept for next years's seed. It was this discovery that saved the silk industry of the world. The income of the State in the French industry which had dropped from 130,000,000 francs a year to 8,000,000 francs, was restored. In India the pebrine problem is even more difficult than it is in France, since there are successive broods of silk worms in the year instead of only one; but the brilliant work of Hutchinson (1920) in India has shown how a more exact application of the Pasteur test may be utilised to stamp out the disease.

Ghosh, Rai-Choudhuri etc., are workers of importance on silk worm in India.

BEE-KEEPING AND HONEY INDUSTRY

The use of honey and its collection from wild hives were known to Indians long before civilization. References to honey-bee are very copious in ancient Sanskrit literature, honey being used as food and in rituals. With the advancement of civilization mankind felt the need of overcoming the difficulty and dangers involved in hunting nests of wild bees. They were induced to live in artificial shelters near human houses and men began to collect honey from those artificial combs.

Modern Bee-keeping.

In 1851, Father Langstrott of the United States discovered his novel 'movable—frame hive' which was fully utilised in the more progressive western countries. Only recently India is making use of this modern method of bee-keeping. In this the frames containing honey-filled combs can be lifted from the hive without disturbing the rest of the bees' nest. The honey from these combs is taken out by a centrifugal machine which allows honey to be extracted from them without the combs being destroyed. The emptied combs are replaced in the hive and the bees immediately re-occupy them, clean them and then start refilling them. In this method the honey is extracted without the loss of comb or bee and the honey thus received is pure, clean and unmixed with extract of larva or egg of bee. The invention of the 'Queen Excluder' makes it possible to confine the queen which is the only individual which lays eggs to one part of the hive—the 'Brooder chamber.'

Jeolikote Beekeeping Station.

The Bee-keeping station at Jeolikote in the district of Naini Tal, U.P. was started in 1938 with a small grant from the Government of U.P. under the sole charge of an amateur bee-keeper Mr. R. N. Muttoo. It has gradually grown up to an organisation of all India importance and has been the seat of research and training for bee-keepers.

Authentic publications on the subject by C. C. Ghosh, R. N. Muttoo, K. B. Lal and others are of value to the bee-keepers.

Kinds of bee in India.

Four species of bee are found in India. They are: *Apis dorsata, Apis indica, Apis florea* and the last one being Melipona belonging to the family Maliponidae.

Apis dorsata: This is the biggest of the bee. It is found in the plains as well as the lower hills. Its comb may be as big as six feet on over-hanging branches of tall trees and sometimes on rocks. Yield of 80 lbs., of honey from a single nest at one extraction has been recorded. Attempts to domesticate this bee have failed. It is vicious, fiery and vindictive in temperapent. It is popularly known as Giant bee or Rock bee.

Apis indica: This bee is easily domesticated and is used in modern bee-keeping in India. It is found both in the hill as well as in the plain. In nature it builds its nest in cavities of hollow trees, in crevices of walls, in unrerground holes and in similar situations where it is protected from the weather. It builds several parallel combs. It has a good temperament and is easily handled. Once established the same colony will continue to inhabit the same hive for years. In the wild state this species yield on an average 7 to 8 lbs., of honey per year while under domestication, with proper management, an yield of 20 to 25 lbs., of honey per year has been recorded. The honey produced by this species is of a better quality than that produced by *Apis dorsata.*

Apis florea: This species is found in the plains. It builds a single nest on the branch of some bush, hedge or similar structure. This bee is a poor gatherer of honey. A colony may yield 1 to 2 lbs., of honey in the year and as such it is not of commercial importance.

Melipona bees: This bee is not at all important to the bee-keeper. This species produces a minute quantity of honey and it is so mixed up with pollen etc., that it cannot be extracted pure.

Yield of honey in India.

A rough estimate of the total output of honey in India is placed at 50,00,000 lbs., per annum. This is only about 1|20th of the total which can be collected in India if the industry is properly organised and if bee-keeping be extensively practised. India is thus losing so much food of high energy value.

Bee-Keeping and pollination of fruit and farm crop.

Bee-keeping has other advantages also. Bee pollinates fruit and farm crops. In Russia honey bee is systematically utilised for obtaning higher yields in certain crops. In India, also bees have been reported to increase the yild of crop like 'Sarson' by about 10 per cent.

Indian Council of Agricultural Research appointed two *ad hoc* committees to study the whole question before the partition of India and are lively interested in the whole problem.

THE FUTURE.

In the history of man, insects have been responsible for more loss of life and destruction of property than that caused by wars floods, earthquakes, fires and famines combined. Their effect on the history of nations and upon affairs of the World are too well known. Had the early Romans recognized the disease - carrying habits of mosquitoes and devoted a small part of their efforts to control them, the map of Europe might have a different colour, today. The present short cut between the Atlantic and Pacific oceans might be in a different place and under different control, had the relation of mosquitoes to yellow fever and malaria been recognised a few years earlier than it was. Had the Texas fever cattle tick not been brought under control, the agriculture and dairying of the Southern States of U.S.A. would have been at standstill condition. One can cite many such instances.

All the aspects of Applied Entomology in India have been discussed, its economic values have been pointed out and its bearings on Nation's health and wealth have been stressed. I believe, its future is bright and assured in a free country.

To-day I put before you what Fletcher (1917) and Pruthi (1948) thought about the future development of Entomological subjects in India.

Fletcher (1917) submitted to the Indian Industrial Commission of 1916-18 an elaborate scheme to set up a central organization for all pure and applied work including medical, veterinary, agriculture, and forest entomology in India. This Bureau was to consist of 20 expert entomologists, 23 Entomological Assistants with necessary staff. The Industrial Commission gave their support to the scheme, but because of the poposed changes at the time in organization of the administration of the country by which Agriculture, Medicine and Veterinary became transferred subjects under the provincial Governments, and partly because of the magnitude of the scheme, it did not receive consideration from the Government of India.

Pruthi (1948) in his Presidential address in the Entomological Society of India Stressed the need for a National Entomological Laboratory for training young men for the posts of Readers and Lecturers in Entomology in the Universities and to carry out research in various branches of Pure Entomology, namely insect morphology, ecology and physiology. For its creation he suggested to urge upon the newly organised Department of Scientific Research whose function is to promote fundamental research work in all branches of science, including entomology.

It is my pious duty to put before you, on the face of facts, my plan of developmental scheme of Applied Entomology for future India. On principle I fully agree with Fletcher's scheme, of course, it will need much expansion as Fletcher's scheme was drawn up 33 years ago when conditions in India were quite different from what they are at present. There is absolute need for the creation of a Central Institute of Entomology for both pure and Applied Entomology. All the eight branches of Applied Entomology already mentioned, namely, Agricultural Entomology, Plant Protection Organization, Forest Entomology, Medical Entomology, Veterinary Entomology. Lac-Entomology, Silk-Entomology and Bee-Entomology should have fully developed Divisions for conducting basic research as well as for training of officers for Institutes of Applied Science in the respective subjects. The works of the proposed Institute will never be in competition with those of the Institute of Applied Sciences but on the otherhand, complimentary to them.

There should have a fully developed division of Pure Entomology in the Proposed Institute for conducting basic researches on Pure Entomology as well as for training readers and lecturers on Entomology in Universities as Pruthi has already suggested.

Considering the potential value of the subject in matters of national health and wealth it is for the country to judge whether to accept it or to reject it.

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SECTION OF ANTHROPOLOGY AND ARCHAEOLOGY

PRESIDENT: CHRISTOPH VON FÜRER—HAIMENDORF, Ph.D.

Presidential Address

PROBLEMS AND PROSPECTS OF INDIAN ANTHROPOLOGY

To preside over the proceedings of the Anthropology and Archaeology section of the Indian Science Congress is an honour to be rated all the higher because the annual session of this Congress is the only occasion when anthropologists and archaeologists from all parts of the country assemble and discuss the progress and problems of the study of man in India. The great distances between various centres of anthropological and archaeological studies in this country deny to Indian scholars many of the advantages enjoyed by their colleagues in other countries where frequent personal contacts between the members of different universities and research institutions and the resultant mutual stimulation and constructive criticism are an essential feature of academic life.

Once a year, however, the Indian Science Congress offers a venue for comprehensive discussions on matters of common interest and I think it will therefore be fitting if I take this opportunity to review briefly some of the main problems that today face the anthropologist and archaeologist in India.

The sciences of anthropology and archaeology cover the whole range of man's existence on earth. They deal with past history as well as with present realities, and the ability of social scientists to make certain predictions regarding the behaviour of human groups draws even the future into the sphere of anthropological interest. Descriptive accounts of contemporary civilization, be they even of photographic accuracy, are therefore not an end in themselves. They provide only the raw material for anthoropological analysis and interpretation which aim at an ultimate explanation of the complexities of human behaviour and at an understanding of the development of civilizations. The ethnographer's synchronic picture of individual cultures must be complemented by the time perspective of comparative studies, particularly in countries where cultural situations are the outcome of the interaction of numerous diverse civilizations. It is in such circumstances that the diachronic approach inherent in the combination of anthropological and archaeological studies is indispensable for an explanation of present day culture patterns. Here anthropoloigcal data cannot be understood except as the result of specific sequences of events that reach back into prehistoric times, and the anthropologist cannot afford to ignore the testimony of archaeological evidence and historical documents. Even where written records are lacking it is sometimes possible to deduce from present distribution of cultures and races in space valuable evidence for their sequence in time.

In India there is a particular need for a time perspective. For here we find on a comparatively narrow space a variety of populations ranging from semi-nomadic food-gatherers to modern town dwellers. While in most other parts of the world rising civilizations tended to eradicate or assimilate earlier and less advanced culture forms, and history appears therefore as a succession of cultures, one taking over from the other, in India civilizations of very different level have co-existed for long periods. This is so because geographical conditions and historic accident have enabled some of the older and less dynamic races to avoid conflict and subsequently eclipse, by moving out of the way of ascending civilization into refuge areas difficult of access and unattractive to the bearers of advanced civilizations. Frequent repetitions of this process have resulted in an unparalleled accumulation of divergent culture types.

Although some of the archaic cultures which preceded the formation of the historic high civilizations may have met with complete extinction, elements of diverse archaic cultures still persist in more or less modified form among the primitive tribes and we may therefore be justified in assuming that some of the culture types found in present day aboriginal India can be typologically correlated with prehistoric cultures brought to light by archaeological excavations.

Let us see whether parallels to this situation can be found in other parts of the world. In Europe and the Mediterranean countries there are practically no survivals of prehistoric civilizations, because every dominant civilization imposed its cultural pattern on all peoples within its orbit and the geographical conditions did not favour the isolation of refuge areas. Older population elements were wiped out or absorbed by more dynamic peoples, and the student of life in prehistoric times has to depend almost entirely on the evidence of archaeological material. Compare with this the position in such marginal regions as Oceania and Australia. There the stone age persisted until the age of discovery and some aboriginal populations live even today in a stone-age atmosphere. The material culture of many of the aboriginal races as found by the early explorers was fundamentally the same as that reflected by the finds excavated by archaeologists. The Tasmanians, for instance, used the same 'palaeolithic' chipped stone implements as are found embedded in river gravels not only of Tasmania, but also of Southern Australia. The correlation of past and present is here complete, and 'prehistoric' cultures merge uninterruptedly into living aboriginal cultures.

India stands in this respect midway between Europe and Austrialia. A cultural development of an antiquity comparable to that of the Mediterranean civilizations has in most areas created patterns of life as far removed from those of the stone age as any in the Western world, and at the same time populations of extremely primitive racial types have persisted almost undisturbed in a style of life fundamentally similar to that of the stone age. Thus the study of archaic Indian civilizations concerns not only the archaeologist, who uncovers stratum after stratum of past cultures, but also the ethnologist, who interprets archaeological material by projecting it against the background of living primitive cultures.

Close co-operation between archaeology and anthropology is therefore an urgent *desideratum* and it is important that the potentialities of cross fertilization are recognized by the representatives of both these branches of the science of man. Yet in India a co-ordination of these two sciences is only in its beginning, and in this context I can do not more than suggest a few lines of approach to problems of common interest.

Perhaps the most important discovery of recent years in the sphere of Indian prehistoric archaeology is the identification and the dating of the neolithic and chalcolithic culture strata which preceded the megalithic culture of South India. Professor Wheeler's successful excavations in Brahmagiri have provided the key to a number of problems which had for long puzzled the archaeologist and the anthropologist interested in the early history of India. To my mind the importance of these excavations to the anthropologist is twofold: We are now able to date the megalithic culture in South India and we have for the first time a clear indication of the position of that neolithic industry which is characterized by the partly or wholly polished celt of pointed butt and oval cross section.

Stone axes of this type have a wide distribution in India, but so far they have known mainly from incidental surface finds. They occur in large numbers in many parts of the Deccan and in the eastern part of Madras Presidency. Numerous specimens have also been found in the area between the upper course of the Narbada and the Jumna, and there are several finds from Bihar, Bengal and Assam. This wide distribution suggests that the pointed butt axe belongs to a civilization which influenced large parts of the sub-continent, and the occurrence of very similar forms outside India emphasizes its importance in the culture scheme of Southern Asia.

In China as well as in Japan the axe of oval or round cross section appears to be the oldest fully developed neolithic implement preceding both the shouldered celt and the highly polished celt of quadrangular cross section. It occurs in Formosa, the Philippine Islands and the whole of eastern Indonesia, but is absent in Malaya and western Indonesia. A few specimens are known from Northern Burma and in Assam most of the neolithic axes found on the surface and obtained from the local tribesmen are of the pointed butt type. West of Assam similar types occur in Bengal and Peninsular India, but it would seem that on the whole the types found in the Deccan and South India are larger and coarser than those of Assam.

Scanty as the archaeological material may still be, the whole evidence suggests that the civilization characterized by the axe with pointed butt is the first major neolithic civilization of Southern and South Eastern Asia. Where its origin lay cannot yet be said, but we are probably justified in associating it with populations who first developed a neolithic economy, *i.e.* an economy based on agriculture and involving a style of life far more settled than of foodgatherers and hunters. While in most other parts of the world such a primitive agricultural economy of 'neolithic' type belongs to the past, in India there are numerous peoples whose culture pattern corresponds in most respects to that of neolithic man even though metal instruments obtained by trade and barter may long have replaced the earlier stone axes. These people are the primitive forest tribes who practise a system of shifting cultivation which necessitates the periodical clearing of forest growth, who use neither the plough nor wheeled transport, and who have usually no other domestic animals than dog, pig and poultry. Some forest tribes of the high ranges of Travancore and Cochin, the Reddis and the Dires of the Eastern Ghats, the Kolams and the Kamars of the Central Provinces and the Juang and Birhors of Orissa and Bihar are all typical examples of such an archaic type of agriculture.

But are we really justified in drawing a parallel between these primitive agricultural civilizations and the neolithic industry characterized by the pointed butt axe? The evidence is so far circumstantial rather than direct but much speaks, indeed for the possibility of such an equation and Professor Wheeler's excavations have provided us with a number of important new clues.

I think everybody will agree that the culture that preceded that first agricultural civilization was one of foodgatherers and hunters, such as survives still among a few small forest tribes in Southern India, *e.g.*, Chenchus, Kadars and Malapantaram. There is equally no doubt that a mesolithic culture of chipped stone implements preceded the first neolithic industry of polished axes. The coming of these axes heralded one of the greatest revolutions in the history of mankind: the transition from a food collecting to a food producing economy. For with an efficient axe man was able to clear the forest and to gain thereby the necessary space for the cultivation of crops. Palaeolithic man armed only *coup-de-poings* or flake tools was able to live *in* the forest, but he did not have the necessary instruments to carve cultivable land out of the forest. We need not resort to the speculative interpretation of archaeological finds to envisage the culture pattern of such early cultivators. Tribes living in secluded forest areas of Peninsular India exemplify the type of economy which must have followed upon the hunting and collecting stage. Though today they use iron axes, we know from experience in other parts of the world that an effective neolithic axe would enable them to carry on their primitive cultivation in much the same way, and it is reasonable to presume that the makers of the first neolithic axes, which in India and large parts of Southeastern Asia were apparently cylindrical or oval, pointed butt axes lived in similar style. The excavations in Brahmagiri showed that the stone axe people lived in more or less permanent houses and we know that such sedentary habits are usually linked with the existence of a stable food supply. In other words the stone axe people of Brahmagiri must have been cultivators and the general level of their material culture indicates that their methods of agriculture were as primitive as those of many surviving shifting cultivators.

We may thus claim to have identified traces of the earliest agricultural civilization of India both archaeologically and ethnologically, and this is more than can be said of many other countries. Moreover, we have evidence that a neolithic culture of no great elaboration persisted in South India until about 300 B.C., when a megalithic people with a fully developed iron age culture suddenly overlaid the earlier civilization. The persistence of a stone age culture until so late a date compels us to revise to some extent our ideas of India's early history.

Right up to the time of the Asokan empire large parts of Peninsular India must have been inhabited by populations comparable to the more primitive of the present aboriginal tribes, and the gap between these living representatives of cultures of neolithic 'style' and cultures of the neolithic age has now been narrowed down to about two thousand years. Considering the very great conservatism of primitive peoples—a conservatism of which prehistoric research provides such ample evidence—it is not unreasonable to assume that despite casual contacts with higher civilizations some of the present-day aboriginals have retained a good many of the characteristics of their neolithic forebears.

This situation is a challenge to Indian anthropologists and archaeologists. For it offers the prospect of tracing the entire sequence of cultural developments from the early neolithic age to present times. Such an enterprise, however, would involve a new orientation in archaeological research. We would have to excavate not in areas known as centres of ancient civilizations, but in places still inhabited by people standing on a comparatively low level of material development. It is there where a 'neolithic' economy persists into our age, that we can hope to find the immediate antecedents of aboriginal cultures.

I do not say that the discovery of neolithic sites would in all cases be easy. The sites used for habitation by some of the more primitive shifting cultivators are not always readily recognizable, and there is no guarantee that present settlements stand on sites inhabited also in ancient times. But in many areas village sites are fairly permanent because they are determined by such immutable factors as the availability of water or level space for building huts. Many of the more advanced tribes have traditional village sites some of which are certainly of considerable antiquity and would probably reward excavation. I am thinking here primarily of such tribes as the Bondos and Gadabas of Orissa, the Kotas of the Nilgiris, some of the Munda tribes of Bihar, the Khasis of the hills round Shillong, certain Naga Tribes and the Apa Tanis of the Assam-Tibet borderlands. Among many of these tribes we find besides the present villages, abandoned sites some of them reputed to have been peopled in the distant past. There is reason to believe that these sites, if systematically excavated, would yield valuable archaeological material which might enable us to link the particular tribal culture of today with prehistoric civilizations of great antiquity.

It is well known, for instance, that neolithic celts with a pointed or narrow butt and oval cross section are found in great numbers in the Nags Hills and it is significant that most finds come from places with similar topographical features. Excavations in such areas might lead to the discovery of that neolithic culture which underlies present day Naga culture. The excavation of a few such sites would be invaluable not only for our knowledge of the growth of Naga culture, but for the understanding of the prehistory of Southeast Asia.

Although we are probably justified in correlating the proto-neolithic industry of the pointed butt axes with the earliest agricultural civilizations on Indian soil, we are not in a position to link this industry with any racial or linguistic stratum. Indeed any attempt to establish such a link brings us face to face with another major problem. Considering the wide distribution of these neolithic axes in South India it would not be unreasonable to link them with the peoples speaking proto-Dravidian languages and this was indeed the hypothesis put forward by R. Von Heine-Geldern in 1928. But if already the earliest neolithic cultivators spoke Dravidian languages, what were the languages of the megalith builders of the iron age who succeeded the stone axe people? It is hardly credible that these bringers of an entirely new culture and style of living spoke languages closely akin to the language of the people whom they supreseded. If we have to chose between the possibility of correlating the stone axe people or the megalith builders with a proto-Dravidian stratum our choice must naturally fall on the megalith builders, who seem to have been the immediate predecessors of the historic Dravidian civilizations. The neolithic stone axe folk probably spoke a language of which no trace has survived, although elements of their race and culture may live on in much diluted form among some of the aboriginal tribes.

The neolithic and partly chalcolithic stone axe people were crowded out and either subjugated or assimilated by a strong wave of new comers who brought the use of iron and the custom of burying their dead in megalithic tombs. The realization that this megalithic culture flourished as late as the second half of the first millenium B.C. and that—at least in the Brahmagiri area—it overlaid a comparatively primitive culture, compels us to view the whole megalithic problem in India from a new angle.

I think that there can no longer be any reasonable doubt that in India at any rate the iron-age megalithic culture of the South had an independent development from the megalithic culture of the Northeast, which still survives among some of the hill tribes of Assam. For the spread of the megalithic culture of Southern India appears to have occurred at a time when the Gangetic valley was already firmly in the hands of Indo-Aryan populations. This confirms my opinion on the essential separateness of these two megalithic civilizations in India, an opinion at which I arrived on purely typological grounds even before Wheeler had made his discoveries at Brahmagiri. It would now seem that the Southeast Asiatic megalithic civilization which spread from Further India to Indonesia and deep into the Pacific, is the older of the two. Characterized by the use of unfashioned stones for memorials, ritual seats, dance circles, steps and avenues, it is found not only among may of the older populations of Further India and Indonesia but also among tribal peoples of Peninsular India such as some of the Bastar Gonds, Gadabas and Bondos. An overlap with the South Indian megalithic culture may have occurred approximately along the line of the Godavari. A special problem are the megalithic elements in Toda and Kota culture. Anyone familiar with living megalithic cultures in Assam and Orissa must be struck by the many megalithic features of a Kota village; how these menhirs, stone seats, stone lined dance places and small dolmens of the Kotas could be derived from the megalithic port-hole cists of the iron-age culture of Southern India is difficult to see. Typologically they appear much closer to the megalithic complex of Southeast Asia.

I have already mentioned the possibility of correlating the iron-age megalith builders of South India with the bearers of the Dravidian languages. That at some time in the first millenium B. C. the megalith builders were the dominant population in many parts of Southern India cannot be doubted, and it is difficult to imagine what tongue other than a Dravidian language they could have spoken. The occurrence of Brahui, a Dravidian language, in Baluchistan might be considered contradictory to such a hypothesis. But this one Dravidian enclave is by no means proof that the whole of Northern India was at one time occupied by Dravidian speaking populations. If such populations reached India by sea—and there is reason to believe that the megalith builders were sea-faring folk—it is very probable that they established themselves on the west coast of the Subcontinent at more than one place. Unfortunately large parts of Northwest India—or politically speaking Pakistan—are archaeological by very little known. But stone cists, though without port-hole, have been found in the vicinity of Karachi, and their patchy distribution would seem to speak in favour of a sea borne migration of megalithic folk. Brahui may have been the language of a colony whose contacts with the Dravidian speaking people of the South were mainly by sea.

However, all speculation on the original bearers of the Dravidian languages is somewhat premature so long as we are unable to reconstruct a proto-Dravidian. Unfortunately Dravidian studies are not yet so advanced and very little work is being done on any of the unwritten Dravidian languages of the aboriginal tribes. These languages, some of which are rapidly disappearing are of the utmost importance to our knowledge of pre-Aryan India, but since Professor Emeneau's successful investigations among the Kotas and Todas, no fieldwork by trained linguists has been undertaken among any of the numerous Dravidian speaking aboriginal tribes. The Linguistic Survey never covered Southern India, and nothing is being done to fill this gap. In its wider sense anthropology includes also the study of language, which after all is not only the principal means of expressing culture, but a cultural manifestation of the first order. Anthropologists therefore cannot view with complacency the complete neglect of linguistic among India's aboriginals, and it is a matter of regret that the Anthropological Department of the Government of India has not been able to organize such field studies by trained linguists, although this important item was included in the department's earlier programmes. Research on the unwritten Dravidian languages is today being carried not only in Paris, Oxford and California, but the workers in those places are hampered by the inadequacy of the recorded material, while in India invaluable evidence remains unrecorded owing to the lack of trained observers. It is only fair to mention, however the very creditable efforts of amateur linguists such as the officers of the Social Service Department of Hyderabad and certain missionaries to whom we owe grammars and word lists of otherwise unrecorded Dravidian dialects.

What are the principal problems in relation to the tribal languages of Dravidian character that concern the anthropologist? I suppose that anybody interested in the ethnology of Peninsular India must at one time or another have put himself the question whether such unwritten languages as Gondi, Kui or Kolami, can be considered the original languages of the tribes now speaking them, or whether such languages were adopted from populations more advanced in material development. *Prima facie* it does not appear very probable that populations as different in physical make-up and general culture as say the Hill Marias of Bastar and the Telugus with their great historic past should always have spoken closely related languages. When we find primitive tribes such as Bhils or Baigas speaking Aryan languages we do presume that their ancestors were among the early Aryan invaders, but take it for granted that they adopted Aryan languages under pressure from politically dominant populations. Similarly no anthropologist with some knowledge of India will assume that the Chenchus or Yanadis spoke always Telugu or conversely that the speakers of the undifferentiated proto-Dravidian languages stood on a level of culture comparable to that of the Chenchus. But when it comes to Gonds, Kolams, Khonds or Oraons, *i.e.*, tribes speaking Dravidian tongues distinct from such written languages as Telugu, Kanarese and Tamil, the position is somewhat different. Here we must exclude the possibility of recent linguistic change. The dialects of the various Gondi-speaking tribes, for instance, have undoubtedly been spoken by these peoples for many centuries and the spread of very similar dialects over large parts of the country suggests that these unwritten languages too look back upon a history of considerable antiquity. In the case of Kui, the language of the Khonds of Orissa, Professor Emeneau has proved this on purely philological grounds. This language contains certain archaic elements which have been lost in all other Dravidian tongues, including the literary languages, but which explain a good many otherwise obscure forms in the written Dravidian languages. This may mean that Kui separated from the main stem before such languages as Telugu, Kanarese and Tamil were fully differentiated or that the Khonds preserved in their mode of speech certain traits which they originally took over from the undifferentiated language of a proto-Dravidian population.

It is as yet problematic whether the Dravidian languages of the aboriginal tribes of Southern and Middle India are directly derived from a common proto-Dravidian, or whether they are the result of a process of Dravidianization comparable to the Aryanization which is still in process in the contact areas of the Central Provinces, Bihar and Orissa. That the vocabularies of certain tribal tongues contain a good many words which are without parallel in other Dravidian languages would seem to speak for the second alternative, and these isolated words may be a residue from older tongues overlaid by a Dravidian stratum. From the ethnological point of view this hypothesis has much to commend itself. It offers an adequate explanation for the racial and cultural diversity of the Dravidian speaking tribes, and enables us to understand how it is that a language like Gondi is today being spoken by people as different in cultural level as the Hill Marias, the Murias, and the Raj Gonds. If during one phase of the Dravidian expansion, a period which must have preceded the Aryan expansion, Dravidian languages were accepted by various aboriginal tribes of different custom and culture, it is quite understandable that linguistic uniformity was imposed on heterogenous groups whose cultural individuality persists even after the replacement or perhaps assimilation—of older languages.

I admit that in all these deliberations we are merely postulating hypotheses; the only way whereby we can reach firmer ground is the organization of systematic research on the unwritten Dravidian languages. Such research could be carried out most effectively by teams of anthropologists and linguists. An anthropological approach will help the linguist in the study of the social context of speech, and the linguist's assistance will be invaluable in the recording of anthropologically relevant texts. The value of such collaboration is not confined to the technical aspect of fieldwork, but extends to the interpretation of the material. Linguistic conclusions can often constitute decisive evidence on historical affinities; and the anthropologist interested in the history of India's tribal populations cannot dispense with linguistic evidence.

In this connection I may remind you of the whole problems of the Austroasiatic speaking peoples which is another unsolved puzzle of India ethnology. What are the main facts of this question? In the Central Provinces, Orissa and Bihar we find a number of languages spoken by more or less primitive tribes, which are commonly known as Munda languages. Though obviously interrelated with each other they cannot at present be connected with any of the other language groups of Peninsular India. In 1907 Professor Wilhelm Schmidt put forward the thesis that these Munda languages are a branch of a language group which includes the Mon and Khmer languages of Further India and to which he gave the name Austroasiatic. He was able to demonstrate a large number of lexical parallels as well as certain important structural similarities between the Munda languages and the Mon-Khmer group. But the material on which Schmidt based his conclusions was very fragmentary and in recent years the soundness of his thesis has been questioned on various grounds. But Schmidt's critics suffer from the same handicap of inadequate material as he did himself, and in the linguistic field no really new and constructive contribution to the Munda problem has been made for more than a quarter of a century. The attempts of Hevesey to connect the Mund languages with Finno-Ugrian languages have not been convincing, and considering the paucity of reliable material Schmidt's interpretation would seem to remain the most satisfactory explanation of the known facts. Some linguists, however, put forth the view that as long as practically nothing is known of many of the Munda dialects, such as Korku, Bondo, Dire, Gadaba, Juang and many more, it is impossible to reconstruct a proto-Munda, and that until this is done there is little point in comparing individual Munda dialects with individual languages of the equally inadequately known Mon-Khmer group.

The answer to this problem is once more systematic field research among the various Munda speakers and that again can best be done by linguists working in co-operation with anthropological field-workers. Without disparaging in the least the indefatigable efforts of those learned missionaries to whom alone we owe whatever is known on some of the Munda languages, we must remember that linguistic and phonetic studies have progressed and specialized to such a degree that the layman, however well acquainted with a language, cannot replace the scientifically trained investigator. Though texts recorded by an anthropologist may be valuable as cultural documents they are as a rule almost useless as linguistic specimens, and in this category I include my own records of texts collected among Tibeto-Burma as well as Dravidian speaking tribes.

But while from the linguistic point of view we cannot register any great advance beyond the position reached by Professor Schmidt in 1907, new evidence on the Austroasiatic problem has come forward from the archaeological and anthropological side.

The coincidence of the distribution of the Austroasiatic languages and of a certain type of neolithic celt, described alternatively as tanged or shouldered adze, was first noticed more than a quarter of a century ago and in 1928 Heine-Geldern put forward the hypothesis that people of Mongoloid affinities entered India from the east, bringing with them a highly developed neolithic culture and the languages from which the present Munda languages are derived. This immigration must obviously have antedated the Aryan conquest of India but at the present stage of our knowledge it is impossible to fix its chronological relation to the spread of Dravidian speaking populations over Middle India. While Heine-Geldern based his thesis mainly on archaeological material it has now become possible to demonstrate northeastern influences on Middle India with ethnographic data.

During my investigations among the Munda speaking tribes of Gadabas and Bondos in Orissa, I found megalithic ritual which resembles the megalithic customs of the hill peoples of Assam in such great detail that the possibility of a fortuitous similarity can be safely discounted. The megalithic complex of both areas includes the erection of menhirs and small dolmens as memorials for the dead, the building of stone circles as assembly and dance places, the use of ceremonial stone seats, the sacrifice of oxen and buffaloes in connection with the erection of memorials, and several other features associated with megalithic culture in many parts of Southeast Asia. It is impossible to link this complex with the megalithic port-hole cists of South India and the only reasonable explanation of the known facts is the theory of a movement of culture and probably also of population from the Northeast into Peninsular India. Megalithic is not the only element linking these particular hill-tribes of Bastar, Orissa and Bihar with those of Assam. The institution of youth dormitories too is common to both areas and so are various minor traits of material culture, such as for instance the peculiar bark fibre skirts of Bondo and Konyak Naga women. It would lead too far to enumerate further ethnographic parallels, but I may mention that several competent observers have noticed a slight mongoloid element among some of the tribes speaking Munda languages.

Thus we see that many of the problems of Indian anthropology cannot be solved unless we look beyond the geographical borders of the subcontinent and view them in the wider perspective of cultural and ethnic movements covering large parts of Southern Asia. Recent development of comparative anthropology in the west, suggest moreover that some of these movement extended further afield than it had hitherto been thought. That Indian cultures exerted a powerful influence on many parts of Southeast Asia has long been common knowledge, but it was unknown that such influences reached out across the Pacific deep into Central and Southern America. During the last session of the International Congress of Americanists held in New York during September 1949, a number of scholars dealt with the problem of cultural connections between Asia and pre-Columbian America. In view of the previous isolationist tendencies of most Americanists, the outcome of their deliberations is truly astonishing and must be considered a turning point in the history of the study of Old and New World relations.

At this congress it was demonstrated that relations between Asia and America extended over long periods, and relate to several independent areas to both sides of the Pacific Ocean. While the spread of certain art styles from China eastwards to America appears to have taken place before the middle of the first millenium B.C., connections between India and Middle America fall into a later period. Professor R. von Heine-Geldern, for instance, made it clear that certain striking parallels between motifs in the Hindu-Buddhist art of Southern India and the symbolic art of Mexico and the Mayan region cannot be explained except by a theory of direct transmission. These motifs, which we encounter in both areas, comprise the lotus, the *makara,* the *kirtimukha,* the cosmic tree, gods standing on crouched human figures and Atlantean figures. Close correspondence of even minor detail precludes the possibility of incidental similarity. The parallels extend also to architectural items, such as temple pyramids, railings of flights of stairs in the shape of serpents and dragon, the corbelled arch and columns in spiral form. Further examples of identical culture traits are the *pachisi* game of India and the *patolli* game of Mexico, the Indian hook swinging and the Mexican *volador,* the use in both areas of parasol, fan and litter as insignia of royalty and rank, the institution of four chief officials, and parallels in cosmological systems. All this suggests a peristent two way traffic between Southern Asia and Middle America which must have begun in the first half of the first millenium A.D. and seems to have continued for several centuries. The papers read by many distinguished anthropologists were supported by a special exhibition in the American Museum of Natural History where the influence of the Hindu-Buddhist art and architecture of southern India—particularly the style of Amaravati— on Mexico and Mayan culture was demonstrated by photographs.

Complementary to the recognition of parallel art styles and ornamental motifs, are the findings of recent botanical research into the origin of certain domestic plants. It has long been assumed that the cultivation of the sweet potato in Oceania is due to ancient contacts with America, and it has now been made probable that the bottle-gourd and certain varieties of cotton are of old world origin and have been introduced into America in pre-Columbian times. In this connection I may mention also the theory of Stonor and Anderson, who hold that maize is an old world plant which was introduced into America from Southeast Asia. This revolutionary theory is based on investigations in the hills of Assam and Burma, which seem to show that the cultivation of maize by the Nagas and other hill tribes is much older than the European influence which had previously been considered responsible for introducing maize to that part of the world.

The assumption of regular traffic by sea between South India, Southeast Asia and America in the first millenium A.D. sets new tasks to Indian scholars who might well attempt to trace the influence of Indian cultures not only in America, but also on the intervening Pacific islands.

We are only at the beginning of the study of Old and New world relations, but the interpretations of the high civilizations of Peru and Central America as the products of a fusion of Asian and American cultures opens up new fields of comparative anthropological researches.

This brief outline of some of the problems of Indian anthropology demonstrates the need for systematic and coordinated efforts by scholars specialized on different fields of study. What are the chances for such coordination and the subsequent intensification of anthropological research in India? This question is directly linked with the organization of anthropological studies in the Indian Universities. For to which institutions if not to the universities should we look for the furtherance of investigations which must be carried out over long periods by succeeding generations of scholars? Research should never be permanently divorced from teaching and teaching without the constant support and stimulation of original research is not worth the time of teachers and students and the funds provided by Government and public bodies.

The place where we are met today provides a shining example of the value of co-ordinnated research and teaching, for the Deccan College Post-graduate and Research Institute has in recent years made most valuable contributions to our knowledge of man in India. This institution, though comparatively small without great financial resources, has attained international recognition by the research schemes carried out by a group of devoted scholars. Among the universities Lucknow and Calcutta have a distinguished record of anthropological research, and Lucknow particularly has developed as a focal point of anthropological studies. In New Delhi and Madras too anthropology has recently been established, and at the Osmania University, to which I had the honour to belong for several years, anthropology is being taught in both degree and post graduate courses. But we cannot help noticing with regret that the provinces which contain the greatest numbers of aboriginals and thus offer most scope to the field anthropologist namely the Central Provinces, Orissa, Bihar and Assam provide as yet no facilities for the academic study of anthropology.

Yet it is just in these provinces that anthropologists could materially assist in the solution of problems of social readjustment and economic change. Although the application of scientific methods to an analysis of human relations is of more recent date than the scientific study of our physical environment, the achievements of modern anthropology show clearly that here we have the means of understanding the working of contemporary societies. Just as physical science enables us to predict natural phenomena, so the study of social interactions enables us to foresee many of the reaction of human groups to given events, provided we have adequate data on such relevant factors as social structure, value systems and social mobility. Indeed the practical value of social science lies largely in this capacity to provide reliable material on which to base prediction. And the ability to predict is the prerequisite for social planning.

Problems of the adjustment of primitive populations to the contact with advanced peoples have for many years engaged the special attention of anthropologists and the student of human relations investigating any particular contract situation can refer to a large volume of comparative material drawn from many parts of the world. The regularities or social 'laws' which emerge from such material will enable him to identify the trends of the social situation which he is studying and predict its probable outcome as well as the potentialities of changing the trend of events by planned intervention.

The scientific approach to social problems is one of detachment, and the social scientist must be continuously on his guard against emotional involvement. Anthropological training which necessitates familiarity with a number of different value systems conditions investigators for such detachment, and it is therefore that in countries such as the United States of America the advice of anthropologists is sought in many situations—not necessarily concerned with primitive populations—where a new and unbiassed approach to a social problem is required.

The principal field for anthropological research is, however, the primitive, pre-literate societies, and it is in this field that a highly specialized technique of enquiry and frame of references has been developed. Systems of land tenure, and kinship, tribal leadership and authority, traditional values, codes of justice and religious beliefs are all factors which the administrator responsible for the welfare of aboriginal populations cannot ignore, and for a scientific investigation of these aspects of a people's life we require the concepts worked out by anthropologists engaged in fundamental research.

In India social planning is today being undertaken on a vast scale and ambitious plans for the development of backward areas are on the programme of most Provinces and States. But as scientists we must realize that to plan the social advance and economic betterment of aboriginal peoples without adequate anthropological knowledge is as impossible as it would be to undertake a programme of public health without the advice of medical experts. There too we may know our ultimate aim, namely the good health of the people, but we are unlikely to achieve it without the knowledge of technical details which only professional training can give.

What then are the prospects for the association of anthropologists with social planning? How can their techniques of analysing backward societies be utilized for the preparation of administrative schemes and what part can they play in their execution? These questions will best be answered by giving a concrete example of the application of anthropological knowledge to an administrative problem. Anthropology has played a considerable part in shaping the future of the aboriginal populations of Hyderabad State, and I propose to outline here the development which was made possible by the application of anthropological knowledge to a scheme of aboriginal rehabilitation and education.

The aboriginal population of Hyderabad consists of a number of tribes differing widely in economic development, social customs, race and language. The most primitive are the Chenchus an ancient community of hunters and food-gatherers who lead a semi-nomadic life in the forests of the hills flanking the Kistna River. Somewhat more advanced are such tribes as the Hill Reddis and Kolams, who cultivate with hoe and digging stick on oft shifted hill fields and are only gradually taking to the more settled cultivation with plough and oxen. Finally, there are the Gonds and Koyas, peasant farmers, who form the bulk of Hyderabad's aboriginal population.

Each of these tribes lives in an entirely different style and presents different problems to the administrator. The anthropological study of several representative groups which preceded the framing of ameliorative schemes took the better part of five years, and it is indeed an indisputable fact that solid anthropological work requires a great deal of time. While it is possible to obtain during a rapid survey of an area fairly detailed information on certain selected aspects of a people's culture, the working of a social system and the economic potentialities of a population cannot be understood except by research extended over a long period. This must be kept in mind if it comes to the application of anthoropological findings to administrative problems. It is next to useless to send an anthropologist as a "trouble shooter" into an area of which he has no previous experience and expect him to submit within a few weeks practical proposals for remedying administrative difficulties or preventing imminent conflict. Before he can express an opinion on matters of policy, he must know at least the basic principles of the tribe's social organization and system of values, and such knowledge cannot be acquired within a short time. Thus the advice of an anthropologist on practical problems is only really valuable if the specific points on which he is consulted relates to populations of which he has an intimate knowledge. It is for this reason that a Government anthropologist employed on a long term basis can be far more effective than an expert engaged for a specific inquiry.

In the case of Hyderabad, schemes for aboriginal rehabilitation were framed only after extensive anthropological information on most of the tribes concerned was already available. It would lead us too far to describe in detail the entire tribal policy of Hyderabad, but a brief outline of the Gond rehabilitation scheme will show to what extent anthropological knowledge can be harnessed to the service of the administration of backward peoples.

The Raj Gonds inhabit mainly the highlands between the Godavari and Penganga River which borders on the Central Provinces. A branch of the great Gond race they were until the 18th century the ruling people in a region called after them Gondwana, but the Gonds of today are simple peasants, tilling land with ox and plough.

The synthesis of Gond and Hindu culture is of long standing and is a process which has continued with varying economic social and political emphasis over a period of many hundreds of years. This on the whole 'benign' culture contact resulted in considerable accretions to Gond culture. The acceptance of such elements as the plough and the feudal system so strengthened the economic and political status of the tribesmen that they were enabled to maintain a position, if not of equality then of partnership with the medieaval Hindu dynasties of nighbouring parts of the country. Under their own rajas, they dominated a large part of Middle India throughout medieaval times, and in Adilabad a feudal system operated until the end of the last century.

During the past fifty years, however, populations from the more advanced parts of the country infiltrated into Adilabad District and their impact on the Gonds threatened to lead to the gradual disintegration of tribal life. In the wooded highlands the Gonds continued to constitute the majority of the population, but in the lowlands they lived in symbiosis with peasant communities of Maratha and Telugu stock, most of whom were immigrants of a few decades standing. These immigrants had succeeded in bringing into their possession a great deal of land previously held by Gonds. The process of land alienation, so characteristic feature of Tribal India, was facilitated by the dscrepancy between the traditional Gond system of land tenure, and the tenancy laws of the State. The Gonds accustomed to the principle of group ownership of cultivable land were slow to understand the necessity of title deeds to secure their rights on the land they tilled; Government officials ignorant of the tribal system of land tenure conferred parts of the ancestral land of Gond clans on individual immigrants, and the Gonds found themselves deprived of a large part of their heritage.

Once the situation had been diagnosed, it become clear that what was needed was drastic and immediate action: protective measures to arrest and prevent any further alienation of aboriginal land; legal recognition of the aboriginal's right on the land that they still cultivated; and new allotments to satisfy the needs of those who had already been dispossessed.

In 1944 the Hyderabad Government decided on a bold policy of land reform, and successive administration, including the present Military Government, have pursued the systematic rehabilitation of the aboriginals. A tribal zone has been created in which no non-aboriginal can newly obtain land, and large stretches of reserved forest have been thrown open for colonization by landless Gonds. All land allotted to aboriginals has been given on permanent tenure and free of charge, and old occupancy has been confirmed by the issue of title deeds.

This stabilization of Gond economy was accompanied by a psychological re-orientation of the tribesmen, for anthropological investigations had revealed that an inferiority complex, which had developed during the years of neglect and exploitation, was one of the Gonds' greatest handicaps. If they were to meet other populations on equal terms they had first to be given self confidence. This could be achieved only by education, and an education suited to the Gonds' particular needs.

The first problem was one of language, for most Gonds spoke none but their own tribal dialect, and in order to be able to hold their own among the other communities they had to learn the language most currently used in the district as well as the State language. But instruction in primary schools would have to be given through the medium of the tribal tongue, which until then was an unwritten language. It was therefore decided to train adult Gonds as school teachers and at the same time to compose basic school books in Gondi. A Gond teachers' training centre was established in a village in the heart of tribal country, and there selected young Gonds were put through an intensive training in Urdu, the State language, and Marathi, the dominant local language. Simultaneously they were taught how to teach children reading and writing Gondi in Nagri script. Today over sixty Gond schools staffed entirely with aboriginal teachers are functioning and two young Indian anthropologists are associated with the administration and development of this aboriginal education scheme.

Parallel with training of prospective teachers proceeded the composition of adult literacy charts, primers and readers in Gondi. It was particularly in this part of the work that the material accumulated during the previous anthropological study of the tribe was of considerable practical importance. For the myths, legends, riddles and songs recorded as anthropological data were used as the raw material for the composition of Gondi books. It was thus possible to produce almost immediately books in the rich idiomatic Gondi of the Gonds' traditional bards and story tellers. The added advantage of these books is the emotional appeal they make to the Gonds, who feel that the schools and the techniques taught in them are capable of giving expression to traditional cultural values. Without the co-operation of trained anthropologists similar results could hardly have been achieved. The importance of an anthropological approach to backward populations lies not only in the sphere of techniques but even more in the anthropologists' basic attitude to customs and values differing from those of his own culture. Interest and respect for the customs and cultural inheritance of other societies is a quality cultivated by anthropological teaching and it is this quality above all which is required of those called upon to guide the educational adjustment of tribal peoples to modern conditions.

The same applies to the organization of a workable system of tribal jurisdiction. Conditions in the aboriginal tracts of many parts of India are so different from those in towns and advanced rural areas, that an extension of the ordinary system of civil and criminal jurisdiction to aboriginals is often impracticable. The need in such areas for a simplified administration and procedure of jurisdiction adjusted to aboriginal societies has recently been recognized by the Constituent Assembly, which approved of the notification of special 'scheduled areas' both in Provinces and States. Hyderabad has already enacted such legislation and "Tribal Areas Regulation" provides for the exclusion of many subjects concerning aboriginals from the jurisdiction of the ordinary civil and criminal courts and for the constitution of tribal panchayats vested with both criminal and civil powers. These tribal panchayats administer traditional Gond law and are empowered to deal with all cases relating to marriage, property and inheritance. Officers with anthropological training are now engaged in collecting the data on the basis of which it will ultimately be possible to codify Gond law.

The establishment of Schedulated Areas in several Provinces offers wide scope to Indian anthropologists, but at the present time, we must view with some anxiety the discrepancy between the country's obligation to look after the welfare of 23 million aboriginal and the number of trained anthropologists available. Unfortunately we are here faced with a vicious circle: the paucity of positions offered so far by the government of Provinces and States to professional anthropologists discourages students from taking up higher studies in anthropology, while the shortage of qualified anthropologists would make it very difficult to provide suitable personnel if governments should suddenly decide to associate anthropologists to a greater extent with the administration of tribal areas.

In conclusion I should like to emphasize that anthropology is not solely concerned with the more primitive forms of society but that it can contribute to a better understanding of any society even the most advanced. Its techniques enable us to study the structure, traditional values and psychological attitudes of societies other than our own, and by furthering the understanding of foreign cultures anthropology can materially contribute to a prevention of conflicts and the growth of tolerance between communities and nations. During the war American anthropologists were entrusted with elaborate research schemes for the study of the Japanese national character and psychology, because it was recognized that one must know people before one can effectively fight them. But one must know them even better if one wants to live in peace with them.

In a country like India with its complex ethnic and cultural structure the need to promote understanding between different sections of the population and to remove thereby the sources of tension and distrust is no less than in other parts of the world. There is a wide field for the Indian anthropologist and if by objective and scientific study of social processes he can help in bridging the gap between the various communities and races he will have done work of national importance.

37th INDIAN SCIENCE CONGRESS, POONA, 1950

SECTION OF MEDICAL AND VETERINARY SCIENCE

PRESIDENT: DR. M. V. RADHAKRISHNA RAO, M.B.B.S., Ph.D., F.N.I.

Presidential address

OBSERVATIONS ON SOME COMMON DEFICIENCY DISEASES IN INDIA:

I am deeply sensible of the honour you have done me by asking me to preside over the Section of Medical and Veterinary Sciences of the Indian Science Congress this year. I wish to take this opportunity to express my most cordial thanks to you for electing me to this office, which was held before by distinguished Scientists in this field.

DEFICIENCY DISEASES IN INDIA

In a Country like ours, where famine and pestilence are frequent and ignorance and religious superstition are rife, it is not surprising that the incidence of diseases due to faulty nutrition or undernutrition is high. With the advent of the newer knowledge in the field of nutrition, several conditions which had remained obscure before, were traced to deficiencies in the diet. Since the discovery of vitamins, the emphasis was mostly on avitaminoses conditions resulting from the deficiency of one or more of the known vitamins. Thus, the existence of deficiency diseases such as Keratomalacia, Beri Beri, Scurvy, Rickets, Osteomalacia etc. has been well established. Recent researches have, however, shown that there are some clinical entities which are commonly associated with malnutrition in India but the existence of which is not so widely known as the deficiency diseases mentioned above. I propose to briefly discuss with you to-day some of these clinical conditions associated with malnutrition.

I had an unique opportunity of working without interruption in this field of the study of deficiency diseases during the last 15 years and the observations made in this address are based on my personal experience. During my recent visit to the United Kingdom and the United States of America, I had a further opportunity of confirming some of my earlier observations made in this Country regarding the aetiology and treatment of some of the Clinical entities associated with malnutrition, described below:

CUTANEOUS MANIFESTATIONS IN DEFICIENCY DISEASE

I shall first take up cutaneous manifestations in food-deficiency disease. A follicular keratosis of the skin has been described occurring in association with xerophthalmia and keratomalacia by Frazier and Hu (1930, 1931) in China, Loewenthal (1933 a and b) in East Africa, and Nicholls (1933) in Ceylon. Nicholls (1933, 1934, 1935 and 1936), who described the condition among poorly fed labourers in East Africa and also among convicts in a jail in Ceylon, gave it the name of phrynoderma (toad-skin). During the course of an investigation to study the nutritional status of school children in south India, it became apparent (Aykroyd and Rajagopal, 1936) that a similar condition was present in malnourished children.

The popular cutaneous lesions are present mostly on the extensor surfaces of the arms and thighs and are roughly symmetrical in their distribution. In some cases they are also present on the posterolateral aspect of the forearms near the elbows, on the extensor surface of the upper part of the legs, the posterior axillary folds, in between the scapular region, and across the buttocks and flanks. The papules vary in size from a big pin's head to a millet seed and are rounded or hemispherical in outline, with sharply defined edges. Examination with lens shows that the papules are situated at the site of the pilosebaceous follicles, which often show a central keratotic plug. The onset of the papular lesion is insidious, and there are no subjective symptoms. It is usually associated with a dry and slightly rough skin and occurs in children of both sexes as well as in adults.

Clinical examination of individuals showing phrynoderma reveals a poor general condition, usually xerosis or discoloration of the conjunctiva, and often dry hair. Other associated deficiencies, such as angular stomatitis, are found in some instances.

Examination of skin sections obtained by biopsy showed a superficial hyperkeratosis of the epidermis and hair follicles marked dilatation of the funnels of the pilosebaceous follicles by keratotic plugs, atrophy of the sebaceous glands, and impaired function of the sweat glands (Radhakrishna Rao, 1937 a).

Our experience in India has been that most of the people showing the papular cutaneous lesions belong to the poorer classes, whose diet consists mainly of milled rice, a small quantity of various kinds of pulses and vegetables with condiments, and perhaps a little millet. "Protective" foods such as milk, milk products, meat, eggs, and so forth, are consumed only in very small quantities occasionally or not consumed at all.

I have discussed the clinical manifestations and the histological findings in phrynoderma in some detail as there is still some uncertainty as to whether the condition is due to a simple deficiency of vitamin A or whether the etiological factors include multiple deficiences. The histological findings in phrynoderma described above, namely, the primary noninflammatory hyperkeratosis of the epithelium of the epidermis and hair follicles, the involvement of the cutaneous glands and hair derived from the ectoderm, and the absence of vascular changes or hemorrhages in the perifollicular tissues, strongly suggest that the condition is a manifestation of a nutritional deficiency in which lack of vitamin A is an important factor. The evidence presented below also supports this view.

Several workers who did not limit their clinical observations on human keratomalacia to the eye have described changes in the skin as part of the syndrome. A dry, harsh, and scaly condition of the skin is usually noticed in patients attending the hospitals in south India for the treatment of keratomalacia. It was thought that a study of the histopathological features of the skin in patients showing eye lesions characteristic of vitamin A deficiency might throw light on the etiology of the follicular keratosis, or phrynoderma. Briefly described, the principal microscopic changes consist of a superficial hyperkeratosis of the epidermis extending into the mouths of the pilosebaceous follicles, atrophy of the sebaceous glands, and slight atrophic changes in some of the hair follicles (Rradhakrishna Rao, 1937 b). These skin lesions resemble those described in phrynoderma, and the advanced follicular lesions found in the latter differ from the former only in degree and not in quality. It thus appears that the popular lesions represent a late stage of the dry and rough skin.

Further support to the view that vitamin A deficiency is an important factor in the etiology of phrynoderma is given by the results of the clinical investigation of the effect of Vitamin A concentrate on the papular eruption (Radhakrishna Rao, 1938). School children who showed marked evidence of phrynoderma were given vitamin A concentrate (preparation A of the Glaxo Laboratories, England) by mouth in doses of 10,000 to 18,000 I.U.'s of Vitamin A per day over a period ranging from 50 to 140 days. During this period no alteration was made in the diet and no local medication was applied. The beneficial effect of the treatment is illustrated by lantern slides in two cases, both of which showed marked follicular lesions. In both instances the follicular lesions had disappeared after the administration of about 16 cubic centimeters of the concentrate (each cubic centimeter of the concentrate, which contained no added vitamin D, had a potency of 72,000 I.U.'s of vitamin A).

To summarize—Vitamin A deficiency appears to be the predominant factor in the causation of the follicular keratosis of the skin associated with malnutritional states. Other factors, such as secondary food deficiencies, deficiency of essential fatty acids, the stage of sexual development a familiar need for abnormally large amounts of vitamin A, or a racial susceptibility (as suggested by Bicknell and Prescott, 1947), may perhaps influence the development of the lesion.

NUTRITIONAL DIARRHOEA

The next subject which I wish to discuss is nutritional diarrhoea. The belief that sprue is not a separate clinical condition but an assembly of clinical phenomena due to damage to the mucosa of the small intestine (Manson-Bahr, 1941) appears to be gaining ground. Chronic jejuno-ileal inefficiency may be produced by a number of diverse surgical and medical conditions, *e.g.*, gastro-jejuno-colic fistula; ulceration of the ileum, blockage of the lymphatic supply of the bowel (as in tabes mesenterica, lymphadenoma, lympho-sarcoma of the mesenteric glands); malignant disease of the small gut. The importance of deficient diet in the production of chronic jejuno-ileal inefficiency has not however, received adequate attention.

Cases of chronic diarrhoea of obscure etiology which do not respond to any kind of present treatment and slowly waste away and die are seen in hospitals in South India. No systematic investigation of this condition has been carried out, and hence it was thought desirable to study experimentally the effect on monkeys of long continued feeding on poor rice diets resembling those consumed by human beings in India.

During the course of the investigation, 84 monkeys were used, and the experiment was continued for 3 years. The animals on the poor rice diet became progressively weak, lost their appetite, and developed watery diarrhoea. The stools were small pale and contained undigested food. In untreated cases, the animals became steadily worse and died. Addition of milk, sprouted grain and banana to the basal diet improved the condition in the early stages, although these supplements had no effect in the later stages of the disease. By a judicious administration of the supplements when the animal was sick and withdrawing them as soon as the condition of the animal had improved, a chronic deficiency state was produced in which the dominating clinical sign was diarrhoea. In addition, the animals showed various symptoms indicative of vitamin deficiencies. Laboratory investigations made during life showed hypochlorhydria and hypochromic, microcytic anaemia.

On postmortem examination, the jejunum and ileum showed varying degrees of atrophy, this being more marked in the lower part ileum, from about 10 to 12 inches above the ileocaecal valve. Histological examination showed that all the different coats of the small intestine shared in the degenerative process, the mucosa being worst affected (Radhakrishna Rao, 1942).

In contrast to this, the control group of animals fed on a fairly well-balanced diet based on whole wheat, milk, vegetables, pulses, and fruits, resembling that consumed by certain races in North India, showed no demonstrable changes in the small intestine.

A clinical picture similar to that shown by the ill-fed monkeys was reported by McKenzie (1940) in African laborers subsisting on very poor diets. The gastrointestinal symptoms and the microscopic appearances of the gut in these cases were closely similar to those described in the monkey. With improvement in the diet and living conditions on the estates, McKenzie reported that the incidence of nutritional diarrhoea among estate laborers fell remarkably.

During our investigations in the Relief Camps in Bombay Province during the last one year, we had an opportunity of studying a similar condition in displaced persons. The largescale migration of the population from one dominion to the other since the partition of the country had resulted in several problems, one of which was to provide adequate diet to the displaced persons. Before these persons had actually settled down in the relief camps and relief measures were organised, they were existing, for varying periods, on poor diets. The result was that cases of Nutritional Diarrhoea were not infrequent especially during the beginning of last year (1949). In one camp which housed poor destitutes, the incidence of diarrhoea was very high indeed.

Examination of stools showed no parasitic infection and there was no evidence of any infection by pathogenic organisms. Diarrhoea was controlled by the simple dietetic treatment which included administration of butter milk and over-ripe bananas. Once the diarrhoea was controlled the patients were given whole yeast tablets and a nutritious diet. The response to treatment was quite encouraging.

It is gratifying to note that since the introduction of relief measures in the camps and with improvement in the diet and the living conditions in the camps, there was a gradual reduction in the incidence of, and mortality from Nutritional diarrhoea.

To summarize—Clinical experience and experimental work has shown that the health of the small intestine is dependent on good nutrition, and deficient diet may produce irreversible changes in the gut.

HYPOPROTEINAEMIA

Measurements of plasma proteins were made in the beginning of nineteenth century, but it is only recently that the plasma proteins have acquired clinical significance. Of the various causes of this condition, some of which are unconnected with nutrition, the one most prevalent in India is undoubtedly due to the deficient intake of proteins for economic and other reasons. The albumin fraction is the one significantly disturbed in malnutrition.

This problem was also studied in the displaced persons in Relief Camps in Bombay Province. The deficiency-state manifests itself by oedema of the subcutaneous tissues, sometimes general anasarca and ascites, and is associated with varying degrees of anaemia. Haematological examination revealed anaemic condition and lowered plasma protein level in the majority of the cases. Cases of nutritional oedema of this type, though a late manifestation of hypoproteinaemia, were found to improve remarkably with high protein diet alone. The cases so treated showed clinical and haemolotogical improvement. A few cases of nutritional oedema with anaemia, treated with the usual liver extract and other routine dietetic and medical treatment, did not show similar improvement.

The Western workers favour the use of protein hydrolysates to be given orally or parenterally. In general the predigested protein preparations have nasty odour and an unpleasant taste producing nausea at times. Patients are usually reluctant to take the prescribed quantity. In view of this, we thought of utilising dried milk or egg proteins such as Skimmed Milk or whole milk powder &|or egg powder in the preparations of 'chapatis'. Our idea of using proteins in the powder form with 'atta' is perhaps a novel one but our experience encourages us to proceed in this direction and shortly to come forward with some definite conclusion about the quantity and mode of its use.

CIRRHOSIS OF THE LIVER

Investigations carried out in South India showed that dietetic deficiencies are important factors in the causation of the disease (Radhakrishna Rao, 1936, 1937). For a long time little attention was paid to the role of nutritional factors in the causation of hepatic cirrhosis, and only during recent years has the subject engaged the attention of both research workers and clinicians. In view of the topical interest, I shall briefly describe the different clinical types of cirrhosis of the liver met with in India and discuss the etiological factors with special reference to nutritional deficiencies.

Portal cirrhosis of the liver is commonly seen in the poorer class of people in the third and fourth decades of life. The disease is characterized clinically by emaciation, secondary anemia, subicterus, dry skin, atrophic liver, enlarged spleen, prominence of superficial abdominal veins, and ascites. Histologically, the parenchyma of the liver is divided by a collagenous connective tissue network into rounded islands of various sizes containing two or more of the so-called lobules.

From a careful investigation into the personal histories of 120 patients in one series, it became evident that most of the males and all the women and children in the series had never touched alcohol in any form. But some of the male patients occasionally indulged in toddy (fermented palmyra juice) or country-made marrack, and rarely, brandy on festive occasions. In no case was there a history of continuous alcoholism. Most of the patients were nonvegetarians. Dietary studies revealed an excess of carbohydrate in the diet and a deficiency of protein, fat, and vitamins, especially vitamins A, B complex, and C. In general, the diet contained an excess of chillies.

The disease is insidious in its onset, runs a protracted course, and ends fatally. It is not uncommon in children belonging to the poorer classes, and the clinical and pathological manifestations in children are similar to those seen in the adults.

In marked contrast to the portal cirrhosis, a progressive and rapidly fatal cirrhosis of the liver is commonly seen in the children, between the ages of 1 and 3 years, of middle and rich class vegetarian Hindus. The disease is characterized in the early stages by a progressive, persistent, and painless enlargement of the liver, irregular intermittent fever, and constipation, and in the later stages, by gradual contraction of the liver, jaundice, enlargement of the spleen, and ascites. Histologically, the liver shows subacute necrosis of the parenchyma, extensive obliterative lesions of the smaller divisions of the hepatic venous tree and replacement fibrosis; attempts at regeneration of the hepatic parenchyma are usually marked.

The disease takes a high toll of life among Indian children, and its causation is still not clear. Although the children affected with the disease belong to the economically better classes, dietary deficiencies are common both in the nursing mother and in the child, on account of the imposed religious restrictions. Protein of animal origin, *e.g.*, meat or fish, is not consumed by the orthodox section of the Hindu community. It is, therefore, of interest to study how far protein deficiency is related to hepatic lesions in general and production of cirrhosis of the liver in particular.

The irregular intermittent fever and leucocytosis in the early stages of the disease, its progressive nature, rapid course, and fatal termination suggest that the disease may be of the nature of a subacute infection (? virus). This and other problems await solution.

At present, an experimental investigation is in progress in the Department of Nutrition, Haffkine Institute, Bombay, to study the role of nutritional factors in the production of hepatic cirrhosis. This investigation was mainly designed to study the effect of continued feeding of diets containing varying levels of protein (purified casein 5 to 18 percent) and deficient in vitamins of the B2 complex on the histological and biochemical changes in the liver of rats. In addition, clinical studies are also in progress to study the effect of high protein diet supplemented with yeast on the course of decompensated portal cirrhosis. Although it is too early to draw definite conclusions, the clinical studies indicate that a good nutritious diet has a beneficial effect on early decompensated hepatic cirrhosis.

Twenty patients were treated with high protein diets which included skimmed milk powder, egg protein, fresh milk and casein hydrolysates. Vitamin supplements were given in the form of yeast tablets with injections of vitamin B2 complex and liver extract in some cases. The majority of the patients came from the poorer classes and their dietary histories revealed gross deficiency in calories, protein and vitamin intake.

The level of serum proteins was estimated before, during and after treatment as this afforded an objective evidence of the course of the disease. Total protein, albumin, globulin and euglobulin content of blood serum was estimated. A common observation in all the patients before treatment was the fall in albumin and rise in globulin fraction of the serum proteins, thus showing an altered albumin|globulin ratio from the normal. In the globulin fraction, the Euglobulin showed marked increase.

The period of observation during treatment was on an average 5 to 6 months. The results of therapy at the hospital have been quite encouraging. Patients treated with high protein diet showed definite clinical improvement. Ascites, oedema and other manifestations of the disease disappeared in many instances. Clinical improvement was attended with a change in the serum protein level towards normal values.

In addition to the serum proteins, the phospholipoid partition of serum of patients with cirrhosis of the liver was also studied A marked reduction of the total phospholipoids, particularly choline-containing phospholipoids, has been found to be an important feature of all cases of cirrhosis of the liver with ascites. As a result of treatment and with clinical improvement, the choline-containing phospholipoids of the serum showed an increase. This work on the phospholipoid partition of serum in cases of cirrhosis of the liver, before and after treatment, is in progress.

To summarize—Portal cirrhosis in India is associated with nutritional deficiencies, and clinical trials suggest that a good nutritious diet may have a beneficial effect on the clinical course of the disease, if treatment is instituted early in the decompensated stage.

TROPICAL ULCER

The last condition to which I wish to draw your attention is "tropical ulser" or "Naga sore". During recent years, it has become increasingly evident that malnutrition plays an important part in the rapid spread and delayed healing of the ulcer.

The ulcer is generally single, unilateral, and present on the dorsal or lateral aspect of the lower third of the leg or foot. It varies in size from 1 to 4 inches in diameter, with sharply-cut and undermined edges. The base is covered with an ashen-gray slough, and there is abundant offensive discharge.

The occurrence of tropical ulcer has long been noticed among the coolie population employed on tea plantations in Assam (Roy, 1939) and coffee plantation in Coorg in South India (Bopaiya and Radhakrishna Rao, 1942). In both area, malaria hookworm, and anemia are prevalent, and there is much malnutrition. During the last World War, when scarcity conditions were prevalent in certain parts of India, the incidence of tropical ulcer greatly increased, and cases were reported in areas where it was not evident before (Panja and Ghosh, 1944, Radhakrishna Rao, Colah, and Kalle, 1945). Phagedenic ulcer, particularly "Naga sores" were seen in starving and sick famine victims in Calcutta and its suburbs. Similar cases were seen in large numbers in one of the districts in the Bombay Presidency.

Most of the patients whom we investigated were poorly nourished, and some of them showed evidence of vitamin deficiencies. Treatment consisted of rest in bed, good food, shark-liver oil and fresh lime juice by mouth, and external application of a "water-in-oil" emulsion containing sulfathiazole and cod-liver oil. Under this regime, the ulcers healed rapidly, and there was improvement in general condition.

Since the Government began taking adequate measures to improve the nutritional status of the general population by a system of rationing of essential food-stuffs and equitable distribution, cases of tropical ulcer have gradually declined in number, and it is now exception rather than the rule to see a case.

While the importance of trauma in the onset of the ulcer and the effect of chronic debilitating diseases such as malaria and ankylostomiasis and unhygenic conditions cannot be minimized, the evidence presented above suggests that malnutrition is an important predisposing factor.

The importance of malnutrition in the rapid spread and the delayed healing of the ulcer has not sufficiently attracted the attention of the clinicians. Apart from the specific local treatment of the ulcer, attention should therefore, be paid for improving the general nutritional state of patients suffering from this condition.

To summarize—The greater incidence of tropical ulcer in certain parts of India in recent years has been attributed to the scarcity conditions prevalent in these areas, and it is suggested that malnutrition plays a part in the causation of the condition.

I have given you an account of some of the common diseases associated with malnutrition in India. The list is neither complete nor exhaustive. There are a number of other deficiency diseases which are equally important, but time does not permit me to discuss them here. The prevalence of such diseases illustrates the magnitude of the problem of nutrition in our country.

BIBLIOGRAPHY

Aykroyd, W. R., and Rajagopal, K. .. Ind. Jour. Med. Res. 24:419, 1936.

Bicknell, F., and Prescott, F. .. The Vitamins in Medicine, Grune and Stration, New York, 1947.

Bopaiya, M.S., & Radhakrishna Rao, M.V. .. Ind. Med. Gaz. 77:139, 1942.

Frazier, C. N. and Hu, C. K. .. .. Compt. rend. Cong. Internat, de dermat. et de syph. 482, 1930.

Frazier, C. N. and Hu, C. K. .. .. Arch. Int. Med. 48:507, 1931.

Loewenthal, L. G. A. .. .. East Afr. Med. Jour. 10; 58, 1933a.

Loewenthal, L. G. A. .. .. Arch. Dermat. and Syph. 28, 700, 1933b.

Manson-Bahr. .. .. Trop. Dis. Bull. 38:123, 1941.

McKenzie .. .. East Afr. Med. Jr. 17:30, 1940.

Nicholls, L. .. .. .. Ind. Med. Gaz. 68:681, 1933.

Nicholls, L. .. .. .. Ind. Med. Gaz. 69: 241, 1934.

Nicholls, L. .. .. .. Ind. Med. Gaz. 70:14, 1935.

Nicholls, L. .. .. .. Cey. Jour. Sci. 4:1 (part 1) 1936.

Panja, D and Ghosh, L. M. .. .. Ind. Med. Gaz. 79:17, 1944.

Radhakrishna Rao, M. V. .. .. Monograph on 'Cirrhosis of the liver in Northern Circars South India'. Jour. Ind. Med. Assoc. Dec. 1936, Jan.-July, 1937.

Radhakrishna Rao, M. V. .. .. Ind. Jour. Med. Res. 24:727, 1937a.

Radhakrishna Rao, M. V. .. .. Ind. Jour. Med. Res. 25:39, 1937b.

Radhakrishna Rao, M. V. .. .. Ind. Med. Gaz. 73, 461, 1938.

Radhakrishna Rao, M. V. .. .. Ind. Jour. Med. Res. 30:273, 1942.

Radhakrishna Rao, M. V., Colah, R. B. M. and Kalle, R. A. .. .. Ind. Med. Gaz. 80, 128, 1945.

Roy, D. N. .. .. .. Brit. Encyclopaedia of Med. Practice 12:256, Butterworth and Co. Ltd., London, 1939.

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SECTION OF AGRICULTURAL SCIENCES

PRESIDENT: R. L. SETHI., I. A. S.

Presidential Address.

PLANNING FOR AGRICULTURAL DEVELOPMENT IN FUTURE

Gentlemen,

I consider it a proud privilege to preside over the meeting of the Agricultural Section of the 37th Session of the Indian Science Congress and thank the committee for the honour they have done me by electing me the President. I am conscious of my shortcomings as in spite of my long service of 27 years in the Agricultural Department I still feel diffident in taking up the leadership of deliberations on this important subject at the annual gathering of the premier scientific organization of the country. But I hope that with your kind cooperation and help I shall be able to discharge my duties satisfactorily.

HISTORICAL

The subject of my talk is a vast one and one can go on speaking on it for hours without finishing it, but I will restrict my observations briefly to only a few salient problems that need attention for bringing about the desired agricultural development in the country in future. Agriculture, as we know, is the main industry of the country and the welfare of more than 3|4th of the population depends upon. The present day sufferings and shortcomings of the people are due to the serious neglect shown in this industry in the past in all its phases. Before attempting to discuss the future problems, it seems necessary to give an account of the historical background that brought into existence the present state of affairs. I do not want to go very far behind but just to the period before the British rule in India. Agriculture at that time was adjusted with the then village economy. Each village was more or less a self-contained unit. It produced most of the articles it needed for its requirements locally. People grew food crops sufficient enough for their needs, grew cotton and made their own *khadi* cloth, grew cane and made *gur* and other sweets out of it, grew oilseed crops and produced oil with the help of village ghani for use both for culinary and burning purposes. They reared cattle both for milch and draught purposes. In short each village was self-sufficient in its requirements. In the absence of railways and other modern means of communication people had to depend on whatever they could produce locally and therefore tried to become as much self-contained as was possible within the limits of available facilities. They had less wants and were contended and it was then that India was known to be flowing with honey and milk. The rates of a few essential articles as prevailing in the beginning of the British period and later, as reported by Mr. B. D. Verma, retired

Manager, Military Dairy Farms, in his book called Gopalan, page 368, were as follows:

		1857 (Seers per rupee)	1890 (Seers per rupee)	1918 (Seers per rupee)	1949 (Seers per rupee)
(1)	Milk ..	160	64	4	1.2
(2)	Wheat ..	39	25	5½	2
(3)	*Ghee* ..	8	1½	½	1|6

With the advance of British rule, the old order changed and the village economy was upset. Greater stress was laid on the production of such raw materials as were needed in England and other foreign countries for manufacturing consumer goods. Agriculture was exploited to that end and more attention was paid to cash crops which brought more money to purchase more goods than food crops. Whatever shortage of food was there, it was met by import from Burma, Australia, Russia and other countries. Indian markets were flooded with foreign goods and the articles became so cheap and abundant that it became impossible for the village produce to compete with them. This process continued for over 150 years of British rule in India and during this period people lost all taste for the village-made crude articles and preferred fine goods turned out by machinery. The import of finished goods and food from abroad brought forth such a great amount of unemployment in the villages that even to earn Rs. 12 a month a villager had to go in search of employment to the city. It was at this stage that Mahatma Gandhi, accentuated by feelings of extreme poverty and helplessness of villagers, started the *Swadeshi* Movement and introduced *Satyagraha*. Although under pressure of political forces, Government allowed the development of some industries, still these industries being new and depend for every type of machinery on outside countries could not compete with the foreign industry for a long time to come. Such were the state of affairs when the first Great World War came. During this war, the scarcity of some essential commodities was felt but as the war did not last long (4 years—1914 to 1918) its effect was not lasting. *Ghee, ata* (wheat flour) and milk had become dearer but the carry over of consumer goods was sufficient to off-set the scarcity caused by lack of imports. The war did not cause much economic disruption and whatever urge for land improvement appeared in the minds of the then Government, it got subsided with the termination of war and the old order continued again in full swing. This went on for about 20 years more when the second World War came. This war on the modern scale implied total mobilisation of all resources, agricultural as well as industrial, and the European countries were long prepared for a transition as soon as the need arose from peace economy to war economy but we in India were magnificently unprepared in spite of the lessons of 1914-18. This war opened the eyes of the Government and the public and everybody else and brought out the real picture in its true nakedness. It brought out the full consequences of a policy of drift, indifference and apathy on the part of the authorities for many a decade. Prices rose rapidly and there was an increasing additional strain on the transport system and India found herself face to face with food crisis in the country, probably unprecedented in her annals. It showed how much short we were of food and in which direction the agricultural economy was drifting. India's self-sufficiency had been broken. Village could not supply enough food and one of the reasons given was that population had increased and there was not enough food for the people. This may be one of the reasons but it cannot be the sole reason. The real reason for scarcity is that the country is not producing so much as it should and as it can. It depended all these years in imports and the stoppage of import and partition of the country by which a substantial amount of food material was lost to the Indian Union the scarcity became acute. It has taken nearly 200 years for the British Government to destroy the village life and hence it must take at least 20 years, if not 50 years, to reconstruct it and to bring it back to the level of self-sufficiency and prosperity as it was before. The Government of India is now importing food to the value of Rs. 1 crore 25 lakhs per annum. It is a praiseworthy attempt indeed to save the lives in this sub-continent in this manner but this process cannot go on for long without jeoperdising the economic interests of the country. The country must learn to stand on its own legs and that too as soon as possible.

The important problems that need immediate attention to develop agriculture in future, thereby gaining self-sufficiency in respect of food and other agricultural commodities are as follows:

I. BACK TO THE VILLAGE

We must produce more and one of the best ways of doing that is to revert to the old system of making individual units self-sufficient. This is not possible without improving the village in all its aspects. Life in a village is very much different nowadays from the life in the town. There is a big gap between the two. No decent educated youngman likes to go to a village and live there. We will therefore have to concentrate all our energies on improving the villages and to make them suitable for the habitation of educated youth. There should be good roads, good sanitation, good education and medical facilities, electricity etc. to make them worthwhile for the present day educated youngmen to live in.

Sir John Russell, a British Agricultural Expert and Director of the Rothemstead Experimental Station in England, who is considered to be a world authority on agriculture, while visiting India in 1937 to review the work of the Indian Council of Agricultural Research, made various recommendations for improving the agricultural conditions of the country ; and one of the most outstanding recommendations made by him was to bridge the gap between the village and the town and to make the former worthwhile for the youngmen to go and settle in. The writer had the privilege of working as his Secretary-Adviser and accompanied him in his tours throughout the country. Wherever he went, he put questions to persons at various stations engaged on problems connected with agricultural research and development and found that almost all of them came from the villages. He was thus convinced that the villages possessed all the necessary intelligence and energy required to develop the country but these needed to be harnessed properly to improve the existing conditions. Thus, one of the foremost and first essential prerequisites for planning of agricultural in the future is to reshape the village in such a way as to make it good enough for the habitation of youngmen who are at present being lured by the attractions of town life. Already healthy signs are appearing and a trend in this direction is visible in both the educated youngmen and the government; the former due to stress of life in the towns are now liking the agricultural profession and the latter by introducing urgent reforms such as abolition of the *zamindari* system and revival of *panchayat* rule are helping to improve the village life.

II. BUILDING UP OF THE IMPAIRED SOIL FERTILITY

(*a*) *By proper utilisation of dung and other indigenous resources for manurial purposes.*

India's lands have suffered very greatly on account of continued drains during the last one or two centuries on their fertility without replenishment. The chief reason has been the lack of interest of the cultivator to improve his lands due to his illiteracy, the old tenancy laws, fragmentation of holdings resulting in poor economic returns and his continued indebtedness. These factors coupled with export of bones, burning of cowdung and waste of animal and human excreta and other waste products carried over for such a long period brought about such an amount of deterioration of the land that it will take a long time before this loss can be repaired. During all this period we failed even to copy the practices of our neighbouring countries like China, Japan and Korea, who have maintained the fertility of their soils through generations by their own indigenous methods.

In China almost every foot of land is made to contribute material for food, fuel or fabric. Everything which can be made edible serves as food for man or domestic animals. Whatever cannot be eaten or worn is used for fuel. The wastes of the body, of fuel and of fabric are taken back to the field and before doing so, they are housed against waste from weather, intelligently compounded and patiently worked at for one, three or even six months, in order to bring them into the most efficient form to serve as manure for the soil or as feed for the crop. It seems to be a golden rule, with these industrious people or if not golden rule, then an inviolable one, that whenever an extra hour or day of labour can promise even a little larger return, it must be given and nothing be permitted to cancel the obligation or defer its execution.

According to King (in his book of *Farmers of Forty Centuries*) the farmer in China is supporting a much larger population than in any part of the world. In China, Korea and Japan a much smaller area than the whole of the cultivated area of America is supporting 5 times the population of America. Notwithstanding the fact that in each of these countries the soils are naturally more than ordinarily deep, inherently fertile and enduring, judicious and rational method of fertilization are everywhere practised. And not until recent years, and that too only in Japan, have mineral commercial fertilizers been used. For centuries the canals, streams and the sea have been made to contribute toward the fertilization of their cultivated fields and these contributions in the aggregate have been large. The accessible portions of their vast extent of mountain and hill lands have long been taxed to their full capacity for fuel, timber and herbage, for green manure and compost material ; and the ash of practically all the fuel and of all the timber used in the home finds its way ultimately to the fields as fertilizer.

In China enormous quantities of canal mud are applied to the fields sometimes at the rate of even 70 and more tons per acre. So, too, where there are no canals both soil and subsoil are carried into the villages and there they are, at the expense of great labour, composted with the organic refuse, then dried and pulverized and finally carried back to the fields to be used as home-made fertilizers. Manure of all kinds, human and animal, is religiously saved and applied to the fields in a manner which secures an efficiency far above the practices in the Western countries. The International Concession of the city of Shanghai as far back as 1908 sold to a Chinese contractor the privilege of entering residences and public places early in the morning of each day in the year and removing the night soil at a price of more than 31,000 dollars for 78,000 tons of waste. We expend much larger sums in throwing all this away. There is also a woeful lack of care both in the methods of preservation and use of cattle-dung in India.

The present production of cattle shed manure in the Indian Union excluding Pakistan is estimated at 120m tons dry weight. The manure prepared in the villages contains on the dry basis only 0.7-0.8% nitrogen, about 0.3% P_2O_5 and 0.6-0.7% potash. In other countries like Europe, America, Japan and China, the cattle shed manure prepared contains on the dry basis about 2-2.5% nitrogen, 0.5-0.6 P_2O_5 and 1.2-1.8% potash. This includes cattle urine also which in majority of cases is wasted in India.

A good portion of the cattle dung estimated at 40-60% is also burnt as fuel, the loss in this respect represents about 100m tons dry weight. If attempts are made to minimise this wastage of precious manure by supply of alternative fuel and encouraging tree planting in villages, it would be possible to increase the present manure production to a level of 200m tons dry weight or 400m tons fresh weight.

A comparison of production of cattle shed manure and rural compost in India and Japan, where the yields of cereals are more than double of those of India are as below:

	JAPAN	INDIA
*1. Area under cultivation	14.44m acres	200m acres
2. Total quantity of cattle-shed manure and rural compost prepared ..	62.8m tons	200m tons
3. Quantity of Farm Yard Manure per acre of cultivated area ..	4.4 tons	1 ton
4. Quantity of plant nutrients added in the form of FY Manure ..		
Nitrogen ..	52.3 lb. per acre	8 lb. per acre
P_2O_5 ..	20.4 ,,	3 ,,
K_2O ..	44.8 ,,	7 ,,

It is estimated that about 12 lb. of nitrogen is excreted per human being per year and for every pound of nitrogen there is an increase of about 7 lb. of grain. Therefore for every human being there can be an increase of roughly 12x7 lb.—84 lb. or 1 md. of grain and for the whole population of India, if properly utilised, the increase can be put to about 35 crores of mds. Similarly, each animal roughly excretes about 60 lb. of nitrogen, 30 lb. in feaces and 30 lb. in urine and the total population of the animal is

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*Figures have been taken from a note by Dr. Acharya, Compost Development Officer, Government of India.

roughly half of the human beings and if their manure can be conserved properly and utilised, there can be an increase of 5 mdsx 17 crores of animals, 85 crores of maunds. The total increase both for animals and human beings can thus be 120 crores of mds. of cereals. In addition to the above values of nitrogen which this manure would add, it would be the organic matter and phosphoric acid contents that would be still more valuable.

The general system in China and Japan is to apply liquified night soil to crops. In India a scheme was started in 1943 with the object of converting town refuse and night soil in urban areas into compost manure for sale to agriculturists. Sufficient progress has been made in the scheme and there is a good demand for this type of compost manure. The main bottleneck at present is transport. The problem of recovery of the night soil of the rural population is being tackled by introducing Wardha system of trench latrines in villages. The problem being a gigantic one, it will take a long time before appreciable success can be achieved in this direction.

(*b*) *Application of soil conservation practices to cultivated lands.*

Another method to preserve soil fertility is to resort to such farming practices as would prevent soil loss by erosion either by rain or wind. The continued existence and prosperity of most countries have depended on their ability to maintain the productiveness of their agricultural lands. It will not be possible to maintain present production, to say nothing of increasing production, if the soil is permitted to be wasted by erosion and outmoded agricultural practices.

According to Mr. Bennett, Chief Soil Conservation Officer of the United States Department of Agriculture, soil conservation does not merely consist of terracing, contouring, strip cropping, filling gullies or planting excessively steep or erodible land with grass and trees; it is that and whatever else needs to be done to keep the soil permanently productive or make it more productive. It means drainage if the land is too wet, irrigation if it is too dry and it means addition of fertilizers and organic matter if the soil is deficient in these constituents. Every day of delay in applying conservation to the land means just that much more loss of food for the people now and in future and it means also a more difficult and expensive job. There are many causes of erosion in India, the chief being the grazing by cattle. Our cattle population is far in excess of what the land can safely support. This has resulted in overgrazing of the pastures, especially in the foothills and in the forests because of the scarcity of pastures in the plains and lack of enough forage crops or straw for stall-feeding. There is a grevious lack of balance between the livestock and the available feed, and this factor brings in its wake many wrong adjustments in the use of land. An important factor that stands in the way of preventing soil losses and maintaining soil fertility is the size of the holdings. Small and scattered fields situated at distances from the village receive very little or no attention and this results in their deterioration. The wanton destruction of the forests near the habitations has also resulted in an acute fuel shortage. The villagers are obliged to use cowdung, grass, leaves and crop stubbles as fuel to cook their food, thereby depriving the soil of the main available source of manure and organic matter. In an indirect manner defective drainage and water-logged conditions also increase the erosion hazard. Erosion problems in India, particularly in the Punjab and the U.P. have so far been studied primarily from the point of view of deforestation. A beginning has however been made with cultivated lands in some places particularly in Bombay and the Punjab. In the former place construction of bunds across the slopes and in the latter 'wat bundi' built all round the field have up to so far been found to be the most useful conservation practices under Indian conditions. In the United States various conservation practices such as contour cultivation, listing, terracing, strip cropping, rotation of crops, green manuring, cover crops, crop residue management by stubble-mulch farming and fertilizer application are being extensively used to check erosion on cultivated land. Some of these methods such as green manuring, fertilizer application, rotation of crops etc. are already being adopted commonly in India. Measures to improve soil fertility and some useful work on application of conservation practices in dry regions have also been carried out in schemes run for 15 years under the auspices of the Indian Council of Agricultural Research. But the application of full conservation technique in its different phases for cultivated area as developed in America yet needs to be explored in India. The means of approach to the problem lie in two ways, *i.e.* (1) publicity and propaganda and (2) demonstration. The first will involve use of upto date methods to impress upon the farmers the desirability of following well-proved conservation practices and the second will bear fruitful results only after some years as it involves trials in different areas of various conservation practices which have proved successful in improving soil productivity and also experimentation with the methods which have proved successful in foreign countries. It is also necessary that there should be close cooperation between the Departments of Forests, Agriculture and Irrigation, both at the Centre and in the provinces, for initiating and developing different phases of the conservation programmes.

(*c*) *Mixed farming*

Another practice which is extremely useful for maintaining the fertility of the soil is that of mixed farming. The Indian Council of Agricultural Research sanctioned a few schemes to find out the value of mixed farming in different areas and the results obtained under these schemes invariably showed that mixed farming was better than ordinary farming without milch cattle. The advantages of this type of farming are obvious. The cattle produce a large quantity of farm yard manure which can be added to the soil, thereby increasing its fertility resulting in increased crop production. This enables more areas to be released for raising fodder crops and legumes which besides providing fodder for the cattle increase the soil fertility directly by virtue of their capacity to fix the atmospheric nitrogen. Mixed farming makes the farmer more independent of the outside help for manures, economically sound and healthy. The condition of cattle generally serves as an index of his economic condition. If his cattle are poor and emaciated, it can be taken for granted that his land is not being used properly, he is not making good profits and his general condition is unsatisfactory but if his cattle are healthy and well-fed his land would be more fertile, his economic condition would be better and he and his children more healthy. The cultivators generally keep their cattle on maintenance ration. This is a wrong conception as whatever the cattle consume they return with other manifold advantages.

III. MECHANICAL CULTIVATION

Generally great stress is laid on the supply of water and manure to the land and it is considered that if these two things are provided, the results will be good. But another most important thing which needs just as much attention as any other factor is the proper working of the land and good preparation of the seed bed. For this purpose two things are essential—one, labour and the other, suitable implements. Due to the scarcity of labour and the high wages, the time has come when greater use of mechanised appliances should be introduced. In the new set-up when the *zamindary* system is being abolished and the labour is asserting its equality with other better classes of people, the application of labour saving devices has become imperative. Estimates of land area for the year 1940-41 for the undivided India and the States show that the country had 100,00,00,000 acres of land at its disposal as under:

		Acres	Acres
1.	Land under forests	107,000,000	388,000,000
2.	Land not available for cultivation	281,000,000	
3.	Cultivable wasteland	171,000,000	612,000,000
4.	Current fallow	79,000,000	
5.	Cultivated land	362,000,000	
			100,00,00,000

With the heavy pressure of population on land as it is at present, India can ill afford to allow a large area (estimated to be 250m acres consisting of 170m acres of cultivable waste and 80m acres of current fallow) to remain unutilised. Lands infested with deep rooted weeds (*kans* and *hariali*) and under waterlogged conditions will have to be reclaimed. The Central and provincial Governments are already importing heavy machinery for reclaiming such areas. The Government of India are running a Central Tractor Organisation for supply of tractors and other heavy machinery to different provinces for this purpose and sufficient progress has already been made in this direction in different areas. But these heavy tractors are mostly useful for ploughing large areas of fallow lands and deep ploughing of weed-infested tracts. They require large initial outlay, costly operators and, as working period will be generally short, they have to be kept idle for the greater part of the year, thereby adding to the overhead charges. For cultivated areas of which there are about 362m acres in the country (undivided India) and where deep ploughing is unnecessary and may even do positive harm, a smaller machinery capable of being used by general farmers will be more popular.

The conditions in India are very much different from those in America and Western countries. Here the tropical sun, the teeming population, the tiny holdings of the average cultivators, the concentration of rainfall to a limited part of the year with its practical absence for the rest of the period; the long period the lands have been under cultivation without sufficient manure necessary for their recoupment; and the absence of machine-mindedness on the part of the agricultural population—all these factors present problems different from those of the Western industrial countries. Any power-operated machinery that is introduced into this country for working large cultivated areas has, therefore, to take into account the peculiar conditions referred to above and the machinery has to be specially designed to suit those conditions. Except in irrigated lands which form but a fraction of the total area under cultivation, the crops have to be grown and matured only in the rainy season when the land will be soft enough for tilling and the ground will have retained sufficient moisture to bring the crops to maturity. It is necessary that all land should be tilled and seeds sown within a week or ten days after the first monsoon rains. This need is well understood throughout India as it is generally seen in every agricultural village that as soon as there is a heavy shower of rain, every ryot is on his field ploughing the land. It is in order tc have this simultaneous ploughing that every agriculturist maintains a sufficient number of plough cattle so that he can have his lands ploughed and seeds sown within a week or 10 days after the first rains. Any machine that will come into general use in this country should therefore satisfy this fundamental condition. Secondly in the absence of roads or trackway to the fields, the plough should be light enough or the heavy parts readily detachable so as to be capable of being carried by a few men to the field and assembled in a few minutes for use. Thirdly, the cost should be such that a small cultivator having about 15-20 acres or a small group of cultivators of a like area can afford to get a mechanical plough and till the whole of their 15-20 acres within a period of 10 days. The machine should have the capacity to till about 1½ acres a day of say 8-10 hours of working. The total cost should be near about Rs. 1,000. This machine should not be complicated but should be easy to manipulate and should have all spare parts readily available. The power unit should be detachable or made available for use for other work such as pumping, cottage industries and garden cultivation, etc. when the plough is not in use. The frame and wheels may, if necessary, be of timber strengthened by steel plates so that the machine can be made cheaply and repairs can be effected by country carpenters and smiths. If Indian engineers set to work to design a unit to satisfy the above conditions, it can easily be accomplished. Such a machine will soon become very popular and come into extensive use in a short time especially now when plough-cattle are very costly and in short supply. An agriculturist cultivating 15-20 acres requires at present about 2-3 pairs of cattle which, at present day costs, cannot be obtained for less than Rs. 1,000 even for average-sized animals. The agriculturist will not therefore grudge to invest a little more in securing a reliable mechanical plough.

The better tillage and timely work attained by the use of the machine will enable the cultivator to get a greater yield from his lands and will go a long way towards securing to the country's self-sufficiency in food production. The educative value of such machinery to the agriculturist, the impetus the machine will give to the educated classes to take to productive labour instead of looking on to clerical work as their sole aim and the secondary lucrative occupation which this will give to the agriculturist will all raise the standard of living in the villages and tend to put a stop to the migration of villagers to towns and even promote a tendency in the opposite direction.

IV. DEVELOPMENT OF THE RAIN-FED (*BARANI*) AREA

The first and foremost requirement of the farmer is the regulated supply of irrigation water. The Government at present is tackling this question of irrigation under two categories, i.e. one by sanctioning big projects of bunding river valleys such as the Bhakra and the Nangal in the Punjab, the Damodar in Bihar, the Hirakund in Orissa and the Tungabhadra in Madras, etc. but as these projects will take some time to mature and there is urgent necessity to increase the production of crops, the water resources are being increased wherever possible by the other method of excavation of new and repair of old wells, tanks and reservoirs, repairing rivulets and streams and nullahs.

These are intended to supply water immediately during the period till the main projects are ready. At present there are about 30m acres under canal irrigation, 30m acres irrigated by wells and 6m acres from tanks making a total of 66m acres. Altogether about 4|5 of the total cultivated area in the country is dependent purely on rainfall which is ordinarily precarious and badly distributed. To grow crops successfully on this area there is no way for India but to take recourse to dry farming methods. We should be able to reclaim or develop the dry land through understanding the principles of water conservation and acting according to them and thus making most of the water bestowed on us by nature through dew, rain and snow, etc. in growing our crops successfully.

In America, both Canada and the U.S.A., by continued research and experimental work carried out with great expenditure, labour and energy, they have evolved practical methods that have made farming quite safe in the areas receiving 10 inches annual average rainfall. And there are instances, in specially dry years when there was 46 inches rainfall, fairly good crops of wheat were taken. In Canada at a farm in Saskatchewan with the average annual rainfall of about 7 inches a yield of 28 bushel (22.4 md.) of wheat per acre was obtained, while in 1894, which was the driest on record in a period of 20 years with rainfall of only 3.90 inches, 17 bushels of wheat were raised per acre in comparison with the highest yield of 49 bushels, a bumper crop, obtained in 1901 when the rainfall was 20.22 inches, the best year of the period. The rainfall was 1|5 while the yield was 1|3 compared with those of the years recorded. Very encouraging results have also been achieved in Bombay Presidency where by application of dry farming methods in Sholapur, they got from 1.5 to 5.9 times over and above the yield obtained by the local cultivators' methods. Within the next decade we can double the produce through dry farming methods, which is quite possible, as the scope and potentialities of dry farming is stupendous, looking at the areas involved, over 300,000,000 acres i.e. half of the total cultivated area (of undivided India). But unfortunately we are not giving due importance to these methods and are trying to solve the food problem only by concentrating on development by means of big irrigation projects, mechanization of farming with heavy tractors and intensive cultivation.

Dry farming methods, unlike the big projects, do not require heavy outlay. It is simply to understand the principles of nature and moulding our practices according to them. But the difficulties in these methods also are many. Not only thousands but millions of the cultivators of the arid regions are to be enlightened. We are a great nation and fortunately at present free to do as we like. With a capable and a very active person having full knowledge of dry farming at the centre and about a dozen such persons in the various provinces with as many experimental farms at suitable places and some demonstration farms run by educated and interested persons, encouraged and financed by the State to take up the work, the whole situation can be changed in a short period, say five to ten years, and the land can be made to grow not only 40,00,000 tons but 400,00,000 tons more food.

A dry farmer in America with the help of modern implements and four horses cultivates and gets good crops of wheat on 200 acres of land, while the dry farmer here cannot farm efficiently even one-tenth of it. The practice of dry farming however requires more intelligence, more implicit obedience to natural laws and greater vigilance than farming in regions of abundant rainfall. A good deal of research work on different lines have already been carried out in the dry farming schemes sanctioned by the Indian Council of Agricultural Research in the past and a monograph has also been published on the results achieved in these schemes. Steps should be taken to apply the knowledge already achieved in different regions and researches should be conducted on such problems as need further investigations.

V. ERADICATION OF WEEDS

Loss due to weeds, though generally recognised, is far greater than usually realised. It has been estimated in the U.S.A. that weeds cause more than double the combined loss caused by insect pests and diseases. The U.S.A. Chamber of Commerce listed 30 items of waste in the U.S.A. farm of which weed problems were second only to soil erosion. It was estimated that before World War I, about 16.5m pounds sterling per annum were lost by farmers in Great Britain in removing weeds. An overall picture of the loss incurred directly or indirectly on account of weeds in India is absent. However, the few scattered information available about our crop-weed relationship gives some idea about the magnitude of the weed problem in Indian crop husbandry. The *kans* weed (*Saccharum spontaneum*) has laid waste millions of acres of valuable land in the C.P. the U.P., Madhaya Bharat, Vindhya Pradesh, etc. causing an annual loss of crores of rupees for the last so many years. Similarly wild rice is a serious menace to rice cultivation, particularly in the C. P., Bihar and Bombay. It causes loss over 37 lakhs of acres of Biasi paddy in Chhattisgarh division (C.P.) alone amounting to the tune of more than Rs. 22 lakhs annually. The nut grass (*Cyperus rotundus*) which is a troublesome weed of the tropics and sub-tropics is a particularly pernicious weed in India growing in all types of soils all over the country with unusual adaptations for tiding over long dry spells of the year. *Hariali* (*Cynodon dactylon*) infects all types of soils equally severely Similarly *baru* (*Sorghum halpense*), prickly pear (*Opuntia*), *gokhru* (*Xanthium stumarium*), etc. are also noxious weeds invading crop lands to lay them to waste and make them unfit for cropping. In Bengal deep water paddy worth some Rs. 11 crores is supposed to be destroyed annually due to the depradation of the water hyacinth (*Eichornia crassipes*).—(*Basak* Meghnath—*Water Hyacinth Compost Government of West Bengal,* 1948). Among the parasitic weeds, broom rapes (*Orobanche crenua*) has been found to cause serious damage to tobacco crop which in Guntur District (Madras) alone, in 1940, has been estimated to be about Rs. 36 lakhs and in Bombay nearly Rs. 10 lakhs (Kumar—*Indian Farming,* 1942). Similarly other parasitic weeds like striga on sugarcane and millets, Balanophora on coffee, dodder on clovers, Loranthus and Viscium on horticultural crops cause considerable havoc in several parts of India, the estimation of which is difficult. They spoil land and reduce the value of the crops and livestock products and in manifold ways are source of great nuisance to man and his affairs.

Weeds absorb from the soil and transpire large quantities of water. On investigations of the water requirements of some of the typical weeds which infect arable land at Dry Farming Research Station, Sholapur, during 1941-42, the transpiration coefficients at the flowering stage were found to be 556 for *kunda* (*Ischæmon pilosum*), 813 for *hariali* (*Cynodon dactylon*), 1108 for *Tephrosia purpurea* and 1402 for *Tridex procumbens,* while it was only 430 for the typical *jowar* crop. These co-efficients indicate the high water requirements of the weed as compared with those of the cultivated crops. Nijhawan (*Indian Farming,* 1944, pages 58-60) showed that it was possible to save 300 to 500 tons of water in an acre of soil to 6 feet depth by keeping it free of weeds under the dry farming conditions at the Dry Farming Research Station, Rohtak. His later work showed that fallow plots clear of weeds contained 532 tons more water in a six feet column of soil per acre than weeded plots and this quantity of water could produce about 1600 lb. of dry matter of *bajra*. Such huge loss of moisture equivalent to about 5 inches of irrigation and capable of raising 20 maunds of crop can be saved if the land is kept free from weeds. Weeds are harmful in this manner, more so particularly in the hot season in arid regions and in areas of precarious and uncertain rainfall, and the harmful competition is most felt by cultivated crops on light sandy soils.

As regards their demands on mineral nutrients, according to Crowther (*Empire Journal of Experimental Agriculture,* 1946) in Sudan (Geizara) cutting of unripe weeds in cotton at ground level, while they were still growing, conserved moisture till the rains, increased soil nutrients five-folds and led to an increase in the yield of cotton crop by 43% over the normal practice. In India at a conservative estimate the reduction in the yield of cotton caused by *kans* is at least a third of the crop, as stated by Howard (*Agricultural Journal of India,* 1927. page 12). The loss in rice caused by wild rices is 5-30% in the C. P. and Bombay (Salimath in *Agriculture and Livestock in India,* 1937, pages 479-92) and the general crop yield is about 50% due to nut grass (*Cyperus rotundus*) as stated by Pillay (*Indian Farming* 1944—pages 67-68) and is 30% by weeds as a whole as estimated by Luthra (*Punjab Weeds and their Control,* Govt. Press, Lahore, 1938). Weeds also deteriorate the quality of crops by mixing with them. Want of proper cleaning and preparation of crop produce have been underlined in the numerous agricultural marketing reports as the prime causes for the low price Indian crop products fetch in internal and international markets. Advanced agricultural countries have seed testing and cleaning stations, practices and laws regulating the sale of crop seeds and controlling the sale of those containing undesirable weed seeds. India has still to fall in line with such progressive countries for producing weed-clean seeds. Sir R. N. Chopra in *Indian Journal of Agricultural Science* (1940) pages 1-44, describes some 700 poisonous plants in India, a large number of which are weeds, some of which cause considerable injury and some times even death to men and cattle. Kehar (*Indian Farming* 1943, pages 130-31) states that cyanogenetic glucoside is widely distributed in many plants and HCN is found in 148 species of plants belonging to 41 families. Though some of these plants are protected by unpleasant odours, bitter tastes or by spines, etc. the poisoning of animals by such plants are a common occurance in India in spite of the widespread belief that they are protected by some instinct from eating dangerous plants. The annual loss in the U.S.A. due to cattle poisoning is estimated to be over 200 million dollars. Similar losses are noted also in U.K., South Africa, Australia and Germany. In India, where the fodder problem is acute, pasture land policy absent, the natural pastures are over grazed, the limitedly available public grazing grounds infested with numerous poisonous weeds, with the largest cattle population of the world to maintain, the loss due to plant poisoning of cattle will be nothing short of phenomenal. According to Venkatachalam (*Indian Farming* 1943—pages 57-75) the loss incurred annually through poisonous plants in drop in milk yield loss of meat and wool, abortion and sterility, temporary or permanent, injuries to the various organs of the body may exceed 20% of the value of the total livestock of India or nearly Rs. 400 crores. There are two methods of approach to the weed problem, either to keep weeds under such control that their harmfulness is restricted or limited or to work out their outright eradication. Timely and adequate tillage, weed-free seed, good rotation and crop sequence, and quarantine against weed-contaminated imported seeds and feeds should be the chief reliance against weed infection. In the main, every thing that contributes to better farming, constitutes in some degree to weed control. Quite recently harmone weed killers have revolutionised the very problem of the herbicidal control of weeds; some of them (like 2.4 D.-cholorophenoxyacetic acid, etc.) are found to have selective action against Dicotyledonous weeds only, while others (like N:N-D carbo-ethoxyaniline, Isopropylphenylcarbonate, etc.) seem to have the opposite effect being selectively lethal to Monocotyledonous plants, (as indicated by Pearse in *Growth Promoting Substances and their Practical Importance in Horticulture.* CAB Technical Communications No: 20, 1948, pages 71-72). This seems to open up a vast vista of future possibilities in discriminative control of weeds whether it be Dicotyledons or Monocotyledons by the judicious application of the suitable harmones alone. However, this does not indicate that the weed problem as it exists in India can be solved by chemical eradication, much less by these new weed killers only, as the trial on these should be conducted under conditions experienced locally, since weeds vary greatly in their virulence and aggression in different soil-climatic conditions, in relation to different crops. The Indian Council of Agricultural Research has sanctioned schemes for investigations into the chemical aspect of weed extermination at 3 or 4 centres such as Bose Research Institute, Calcutta, Botanical Laboratory, Kanpur, and IARI, New Delhi. The Bose Institute is also investigating the possibility of manufacturing indigenous chemicals locally. About half a dozen important local weeds would first be tried with the chemicals which are commonly used for killing these weeds in other countries. The work, if found successful would be extended to other provinces. The problem needs to be tackled in a coordinated manner with utmost speed to save the tremendous loss caused by weeds to agricultural crops.

VI. CONTROL OF PESTS AND DISEASES

A considerable loss is caused by insect pests both to the field crops and stored grains. The following resolution of the F.A.O. Council passed in this connection in 1948 is noteworthy:

"The Council directs the most emphatic attention to the problem of loss of food by infestation, disease and all other forms of waste. That preventable loss of food on the scale that has been estimated should occur at any time is lamentable enough, but that it should take place under present conditions of shortage is, in the opinion of the Council, perhaps the most deplorable feature in the whole picture of the current food situation. No effort should be spared to lessen waste in all its forms; nothing is likely to bring a quicker return."

The importance of crop protection was also stressed by the Bengal Famine Enquiry Commission who considered the low yield of paddy crop due to a single disease to be one of the basic causes of the Bengal Famine of 1943. The Commission recommended that the Centre and all the provinces should immediately establish plant protection services. Consequently the Directors of Agriculture and Plant Protection Officers of the various provinces and States met in New Delhi in June 1949 and decided upon measures for intensifying work on pests and disease control. It is estimated that about Rs. 500 crores worth of agricultural crops are lost in India due to damage caused by insect pests and plant diseases and also due to damage to grains during storage. Of this about half is on account of losses to food crops. This problem should be tackled energetically and with modern methods of crop protection and storage of grains, and it should be possible to prevent this colossal waste, which is sabotaging the Grow More Food Campaign. Adequate supplies of all pesticides are available and supplies of spraying and dusting machinery are not difficult to obtain at short notice. What is required is an extended staff both at the Centre and in the provinces and States to ensure that adequate and timely use is made of those materials which are useful in combating pests, fungi and all the other lesser known diseases which attack all kinds of food crops. Researches should also be undertaken on the manufacture and use of cheap insecticides, fungicides, etc. by using indigenous material. The most serious disease caused to any one single crop is that of the rust on wheat. The damage in certain areas is so extensive that even enough seed is not left during some years for sowing. Intensive work has been conducted in this respect for over 20 years in the country under the auspices of the ICAR and very useful information of the causes of disease and the probable methods which should be adopted to eradicate it have been indicated. It is said that the only effective method of controlling this disease is to produce the disease-resistent varieties of the crop. For this purpose a scheme has been in progress in Simla for over a dozen years and the work has reached a stage where varieties that are resistent to individual rusts separately have been evolved and these are being crossed to produce a variety that will be resistent to all the three rusts simultaneously. Some strains of this multiple cross have reached fourth and fifth generations, and it is expected that very soon desirable type will be made available for distribution for trial purposes in different areas. If this work proves to be successful, this will be the first of its kind as so far no single variety has been produced which is resistent to all the three rusts together. The Government of India have quite recently sanctioned a co-ordinated scheme for intensifying mycological and botanical work on this most serious disease in the country. As far as State action is concerned, legislation has been passed in India embodying two lines of defence against insect pests and fungous diseases. The first one prevents the entry of foreign insects into the country while the second seeks to eradicate them. The Plant Protection Directorate of the Government of India is given charge of this work and the Storage Directorate of the Food Ministry is tackling storage problems under different climatic conditions. As the appearence of diseases and insect pests is intimately correlated with the elevation and weather conditions of the locality, the whole problem also requires to be intensively studied, taking into account the bearing of these aspects on this problem. A crop weather scheme has been sanctioned by the Indian Council of Agricultural Research and a large number of observatories have been established in different parts of the country to corelate crop production and the appearence of the diseases and pests with the weather conditions. But as has been indicated above, the amount of damage caused by insect pests and diseases is so large that immediate attention to check this loss with the help of plant protection services in different provinces and States is urgently called for. Prevention of this loss alone can make India more than self-sufficient in respect of food and can go a long way in increasing the crop yields in the country.

VII. BREEDING FOR QUALITY

In future breeding programmes, emphasis should be laid on nutritive values of different varieties. This aspect is very important and should be paid greater attention to in future work. In wheat a scheme was sanctioned to investigate the milling and nutritive quality of wheat at Lyallpur with a view to ascertain the protein contents and vitamin contents in different varieties and the extent to which the nutritive value of wheat can be imporved upon by crossing highly nutritive types without reducing their palatability. Some results of practical value were achieved at Lyallpur but since that laboratory has gone over to Pakistan, a new scheme for the Eastern Punjab is under consideration as this is the most important wheat growing area of the Indian Union. In pulses and millets, protein content in some types was investigated in the co-ordinated pulse and millet scheme in progress under the auspices of the Indian Council of Agricultural Research. In the C.P. for example, the white-seeded gram was found to contain higher percentage of protein (23%) as compared to gold-seeded (21%) and the brown seeded varieties (16-17%). Further work in this direction is immediately called for as pulses and millets form an important part of the Indian dietary.

In rice, a scheme of research on quality in crops was sanctioned by the Indian Council of Agricultural Research in the past. It was found that parboiling invariably improves the milling quality of raw rice. Parboiled rice loses less of soluble matter on cooking than raw rice in so far as very little matter is removed with its *kanji* (drained-off liquid) as compared to the *kanji* from raw rice. The proteins are found to have diffused into the deeper layers of the endosperm in parboiled rice. Parboiled rice does not lose so much of the proteins on milling and polishing as raw rice. The presence of the amino-acid, tryptophane, in the proteins of the aleurone layer in rice makes rice a good body-building food, provided it is not lost in polishing. Polished rice is deficient from the nutritive point of view and we should concentrate on measures for pounding of rice by which we can get better nutritive rice and more of it.

Much of the protein and mineral constituents of the rice grain is located in the external layers, namely, the bran and embryo. Ramiah and Mudaliar working at Coimbatore have established that coarse grains have thicker bran layer than fine grains and the thicker the bran layer the more nutritious is the grain. Quality investigations carried out by Sreenivasan at Bangalore have shown that coloured and coarse rices generally contain larger amount of protein and mineral matter. Such varieties also require greater amount of polishing than finer rices for producing white grain. Under ordinary conditions of milling the extent of loss of essential constituents from coloured or coarse varieties is therefore less than in the finer varieties. Recent work of Hinton in England has established that the greatest concentration of vitamin (thiamin) in the rice grain is in the scutellum, the tissue surrounding the embryo and hence in breeding for nutritional quality in rice, attention should be paid to both the bran layer and the scutellum. Ordinarily, there is 7-10% of protein content in the rice grain in India. Bigger coarse red rice contains 10% protein but it is claimed that certain varieties contain as much as 13-16% of protein. It is extremely important to produce rices of higher nutritive value for eating by the large number of poorer classes who cannot afford to add other protein food in the form of pulse or fish and subsist on rice alone. The studies should be carried out at the Central Rice Research Institute, Cuttack.

As regards effect of manures on the quality of rice crop, there is some evidence to show that the nutritive value of rice is influenced by the kind of soil and application of fertilizers. Rice grown on good soil contained higher percentage of soluable carbohydrates than rice grown on poor soil, the addition of nitrogen to a deflocculated silt-loam increased the percentage of protein in rice and the iron content in the earhead and straw was greater when the crop was grown on soil possessing high soluable iron in the ferrous state. The thickness of the aleuron layer is favourably influenced by manuring with green leaf. These few results point to the need for further research in this promising line.

VIII. EXTENSION SERVICE

A large number of experiments has been carried out in different provinces on manurial, varietal and agronomic aspects of different crops and sufficient information has been gathered in these respects in the past but despite this accumulation of knowledge only a few recommendations of the provincial Departments of Agriculture have so far been adopted by the general body of cultivators. Speaking generally, the crops grow well on Government farms wherever situated but little improvement is visible even in the fields of cultivators adjoining these farms. The question of translating the results of research into general practice has been engaging the attention of the Indian Council of Agricultural Research for a long time and they have been inviting experts periodically to review the work of the Council and to suggest ways of effecting improvements in future. Sir John Russell, who reviewed the work of the Council in 1937, emphasised in his report the need of carrying out simple experiments on cultivators' holdings to bridge the gap between the experimental stations and the cultivators fields. But unfortunately the position has remained very much the same and there has been little improvement in introducing improved practices in the cultivators fields. In 1947 Dr. Stewart examined the work and made suggestions for the planning and conduct of future experiments. According to him, failure to achieve, under ordinary agricultural practices, large scale reproduction of the high yields of many Government farms is due to two main causes, viz.

(1) The soils of India have been undergoing progressive impoverishment over a long period and, because of his own poverty, the cultivator cannot afford the cash outlays which are involved even in relatively small scale improvement measures.

(2) There is a lack of sound information on what exactly is needed to overcome the poverty of the soils under the widely differing conditions obtaining throughout India.

The first of these has widespread social and administrative implications and requires the attention of various departments. The second requires more careful and detailed work to elucidate the effects of various factors which have made individual, aggregate and cumulative contribution to the high productivity of Government farms. The present knowledge of the effects of individual nutrient supplements under different soil and climatic conditions is inadequate. To investigate this fully, consideration should be given in the planning and conduct of future work to two main types of experimentation:

(*a*) Simple experiments in fields of cultivators to test the most promising results of past work,

(*b*) Research and detailed experimental work at carefully selected centres supplementary to existing Government farms.

Dr. Stewart suggests that the scope of the crop-cutting survey organisation should be enlarged to include simple experiments in cultivators fields. He considers that there will be no better means of obtaining quickly and cheaply the much needed information on manuring and other aspects of agricultural improvement in India. As however the staff and the money cannot be obtained all at once, a modest beginning may be made with one district in each province. The number of experiments per crop per annum in each district should be about 30 spread out in different villages. He strongly recommends the carrying out of soil analysis of the areas where these experiments are carried out with a view to be able to correlate the soil data with the crop growth in order to find out the reasons of negative and positive results of application of different manures. This work has been neglected in India in the past and should be carried out in the manurial trials in future.

In the United States, the Extension Service is an educational agency run by the co-operation of the Federal and State Governments. Its main function is to educate (1) the farmers in better farming methods, (2) the farmer's wife in better cooking and house-keeping methods and (3) the farmer's children in better recreation, health and hygiene.

The Service operates through a number of District and County Agents working under the control and supervision of State Directors of Extension Service. The nerve centre of these activities is the State Agricultural College, where the State Director is located and works with his Assistants and Advisers. The County Agents and their Assistants are in close contact with the farmers and their organisations.

They carry the result of researches and better farming methods to the farmers on their fields by actual demonstration and also help to solve the problems of the farmers with the assistance of Experts. The 48 States constituting the United States are divided for administration purposes into 3107 counties. The total number of extension workers employed in this service in 1948 was 11,440 as against a number of nearly 1,500 when the service was started initially in 1915. The total expenditure on the work during the fiscal year ending on June 30, 1947 was 53 million dollars, which is equivalent to Rs. 17.7 crores. Nearly half of this expenditure is borne by the Federal Government and the other half by the State Governments, County Administration and the farmers, organisations. The main distinguishing feature of the extension service is the field demonstration carried on through voluntary local leaders. The Extension Service man is only a friend and a guide to the farmer to whom he brings information about the latest improvement practices and whose problems he carries to the higher quarters for being tackled. In India the question is more complex because of the wide gap existing between the research station and the cultivators fields and the poor economic conditions of the cultivators. The demonstrations of the type adopted in America have been carried on for a long time in India without much result. The solution seems to lie in the directions pointed out by Dr. Stewart. The Ministry of Agriculture has appointed a small committee of experts to go into this question and to suggest a model plan suitable for Indian conditions, which may be adopted in different provinces and States after such modifications as may be found necessary by the Governments concerned. The committee have prepared the broad outline of a plan which is receiving consideration of the Government.

IX. STAFF AND GENERAL

A. For research it is extremely important that persons who have been found suitable for particular jobs should be retained permanently on these posts and not shifted. At present it often happens that research workers are transferred from one post to another thereby all the experience gained by them in a particular branch of science is lost both to them and the country. In England, America and other European countries research workers remain on their posts permanently and would get all the emoluments and other benefits which they would get by shifting to other administrative jobs. There is thus no attraction left for them to seek another post carrying a better salary. In this way the scientists become specialists in their own lines in course of time. Similar measures should be adopted in India also where research talent is available in abundance but is often wasted by continued shifting of workers from one job to another.

B. For development and posts of directions only sound agriculturists with long experience of practical work in the field should be appointed. It often happens that in the agricultural service people are appointed to responsible positions who have never studied the science of agriculture in their career. This defect needs to be rectified. Like doctors and engineers, who cannot become proficient in their respective branches of profession unless they have mastered their sciences after long practical experience, agriculturists also cannot develop proper capacities for direction and initiative till they have acquired sound knowledge of the field work. Laymen often consider that agriculture is an easy subject and consists only of ploughing the land and raising the crops but actually the things are not so easy as they look. It is the proper understanding of balanced application of various factors pertaining to different sciences such as chemistry, botany, mycology, entomology, animal husbandry, engineering, forestry, statistics, meteorology, etc. in relation to crops, that makes one a proper agriculturist and this is acquired only after sound agricultural training and grapling with the cultivators problems for a long time.

C. Another point of general interest to which I finally wish to draw attention is our weakness for flare of the West. As a result of our subjugation for nearly 150 years we have developed a sense of inferiority complex and looking upon everything European and American, be it workers themselves or their literature, as a hall-mark of efficiency. This is a wrong conception and we should try to get rid of it as early as possible, as it is causing a lot of harm to the development of initiative and drive in the minds of our young workers. If an estimate is made of the results of our various experts and deputations to outside countries and of outside experts to our country, the sum total of the effect on cultivators fields, so far as agriculture is concerned, would be found to be very little. I do not mean to say that contact with the outside world and scientists of other countries should be stopped altogether or we should cease to adopt their methods which suit our conditions but what I want to stress is this that merits of our own workers who may be doing more useful work in their own humble way should also be recognised and appreciated. We often proudly give references of the foreign workers and their investigations in our writings and talks to impress on others the importance of our researches, but we fail to take note of investigations of greater practical utility which may be available at our next door. Future development can only be possible as a result of initiative and zeal brought from within and not from outside. The conditions in India being altogether different from the Western countries we cannot succeed in our mission by simply copying outside methods. We will have to evolve our own ways and means of effecting improvements by studying closely our own local problems and encouraging our local talent of which there is no dearth.

37th INDIAN SCIENCE CONGRESS, POONA, 1950

SECTION OF PHYSIOLOGY

PRESIDENT: SHRI KALIDAS MITRA, M.B., D.P.H., D.T.M. & H., F.N.I.

Presidential Address

PHYSIOLOGY OF HEALTH AND PHYSICAL FITNESS

I am extremely grateful to the Physiology (Sectional) Committee of the Indian Science Congress for the honour done to me. I very fondly hope that my colleagues engaged in public health work would reciprocate this kindly gesture by joining the annual meeting of the Congress in ever increasing numbers. Their participation would certainly enrich the discussion of this section and, such joint deliberations may lead to a better understanding of the human organism and his potentialities.

PLEA FOR A NEWER OUTLOOK

The fact cannot be denied that from the middle of the nineteenth century onwards there has been an unprecedented efflorescence of knowledge in the realms of physiology, medicine and other sciences related to the well being of man and his environment. It may be somewhat paradoxical, that in an era of exuberance of research there should be any cause for complaints. But wants are often acutely felt in the midst of plenty. Quite a few of my learned predecessors in this chair have in their presidential addresses stressed on the need for an orientation in the existing methods of teaching and research in the subject. The need for a changed outlook has been advocated by physiologists in other countries also. Sustaining moral strength from the precedents quoted above I feel emboldened to dwell on one of the essential gaps in the knowledge of human physiology. The particular lacuna, I contemplate referring to, in our knowledge of human physiology, should be viewed with great concern in the interest of the science itself and in its possible applications to the betterment of life and living of the human race.

In the flush of our knowledge on the conquest of environments coupled with our ever-growing enthusiasm for social ventures the terms 'buoyant health' 'positive health' 'optimum physical fitness' and similar expressions have not only been coined within the recent years but freely used in scientific literature. The concept of all these states of the human organism, however, are still nebulous and hazy to say the least. One has off and on heard of A1, or C3 levels of health referred to by qualified doctors and health minded non-medical persons, but I must confess that in retrospect I have failed to visualise such standards or categories of health.

Here a very pertinent question may be asked whether a study of the different phenomena which create and maintain health fall within the domain of Physiology. The answer need not be a laboured one. The opening paragraph of a well known textbook[1] on the subject reads that physiology 'signifies the study of the phenomena presented by living organisms, the classification of this phenomena, and the recognition of their sequence and relative significance, the allocation of every function to its appropriate organ, and the study of the conditions which determine each function'. According to this definition studies on health and physical fitness which is none other than investigation, appreciation and proper appraisal of the phenomena which determine the physique, organic efficiency, and motor as well as sensory fitness of human subjects fall within the domain of physiology. But the fact can hardly be denied that in the development of knowledge on human physiology from the early days when the studies veered round the phenomena of circulation and activity of frog's muscle, to the present day researches, there has been very little evidence in the studies of a definite bias on health and fitness. To put it bluntly, scant attention has been paid to integrate the phenomena associated with optimum physiological conditions of the human body as a whole.

PHENOMENA OF HEALTH—A NATIONAL ISSUE

In the present day struggle for survival detailed knowledge of the different phenomena associated with the optimum state of 'health' or physical fitness has assumed the importance of a national issue. It must however be understood, that by making a specific reference to physical fitness the importance of emotional, intellectual or social fitnesses are not underrated. But the phenomena determining mental health have been kept outside the purview of this address for reasons more than one. Though the precise relation of health to physical fitness and vice-versa has not been established it would not be wrong, in the present state of our knowledge, to presume that health and physical fitness often go together. No state can maintain its independence, integrity, or its very existence, unless it can ensure the supply of efficient man power to its industries, agriculture, and last though not the least to its defence services. Consequently the importance of the study of the physiology of health, has transcended the limits of purely academic interest or dream of social workers.

There is yet another utilitarian aspect of this problem which has become increasingly evident in most of the countries of the East, and also in some of the war ravaged territories of Europe. The people in these countries have suffered intense privations through shortage of food and housing during the last six, seven or eight years. The concurrent rise in prices all over the world has reduced the purchasing power of the people, thus bringing in its trail an appreciable incidence of lowered state of health, popularly described as mal—or under-nutrition. A big problem which is facing the administrators of health organisation in such countries is one of determining health standards by suitable yardsticks. In matters of relief and rehabilitation the medical advisers to Governments have often to assess whether one group of people are in a lowered state of health or nutrition as compared to the other groups. Such information is essential in the matter of determining the size of the rationed foodstuff, distribution of milk and other supplementary foods, allocation of housing and other measures for relief.

One can easily imagine the embarrassment of a public health officer who was once asked by a senior administrative official of the then Government of undivided Bengal in 1944, soon after the Famine, to report within a few days which of the districts or subdivisions in the province needed more relief than others, and to grade the regions in descending order of nutritional status of their residents. This problem was presumably no different from the one which some of the health experts in Allied Control Commission in Germany and elsewhere in 1946-47 were faced with, in deciding the size of ration and priorities for different areas and groups of people. In regions devastated by wars or suffering from economic disruptions consequent to having been militarily occupied by foreign belligerants, mobilisation of limited food resources and judicious distribution thereof on a physiological basis were problems of serious magnitude. Such problems have cropped up in the past and are very likely to recur unless the food problems in the world are fully solved. The chances of such an event taking place in the immediate future are however very remote. A comparative study of vital indexes may be of some value in long term disease surveys but not in the circumstances referred to.

The situation would have been different if so called signs of nutritional deficiency could to any appreciable extent be relied upon to assess the state of lowered health or nutrition. Experience of nutrition workers in India[2] and the reports [3-7] from the various prisoner-of-war camps and finally the observations of Adcock *et al*[8] have definitely established that the percentage incidence of nutritional stigmata such as phrynoderma, xerosis, Bitot's spots, dryness of the skin, angular stomatitis, glossitis, scrotal dermatitis or cheilitis in any group of people could not *per se* indicate the over-all state of health or nutrition of that group. Large number of people even after losing appreciable percentage of their weight did not exhibit these signs; whereas instances have been recorded when prisoners-of-war developed some of these syndromes a few days after they were put on perfectly balanced diets subsequent to their release [3 & 5] Till such a time when the physiological and clinical implications of the so called deficiency conditions are fully understood, it is expedient that these indexes be not freely and frequently quoted, as it has been done in the past, to indicate the health or nutritional status of population groups. Probably at this stage the issue raised is becoming still more complicated by the addition of another term 'nutrition' in addition to 'health' and 'physical fitness'. But the concept of nutrition would be discussed later on.

CONCEPT OF POSITIVE HEALTH

In the domain of preventive medicine the concept of Positive Health is becoming more and more popular. But in the achievement of that objective the essential pre-requisite is that the term Health should be defined and its limits established in order to grade the condition in its positive aspect. In an interesting and thought provoking article on the positive aspect of health, the author a medical man has sarcastically though very aptly remarked[9] that is presumptuous to profess the science of health when its definition still eludes us. In medical research and teaching scant attention has been and is still paid either to the study of the physiology of positive health, or to the investigations on how human beings react to their environment before finally crossing the clinical threshold. In the curriculum for medical studies enough emphasis is laid on diagnosis and prognosis of diseased states, only with the result that the finished product from a medical school or college often finds it difficult to arrive at a reasonably accurate diagnosis of the health status of such human subjects as may not be actually ill.

'Health' as defined in the Constitution of World Health Organisation 'is a state of complete physical, mental and social well being and not merely the absence of disease or infirmity'. Such a definition is definitely an advance on the traditional negative concept, *of health being synonymous with absence of disease.* Yet it has left much to be desired because the definition is far too broad and vague. Let us hope that comprehensive studies on the physiology of health would be taken up in the near future and thus enable this Organisation to define health with reasonable precision. The fact is well known that in any physiological process, or as a matter of fact in any biological phenomenon which can be determined by accepted methods, the range of variation is often an extensive one. Any wide or noticeable departure from norms, can be easily determined and interpreted as a diseased state of the organism. But within the wider range of any particular physiological process the limits of the necessarily shorter optimum range, which may indicate a condition of complete well being, can only be established after careful investigations. It would also be necessary to determine which of the physiological phenomena or groups of phenomena can be used as the criteria for determining different grades of health in its positive aspect.

NEGLECT OF STUDIES ON THE HEALTH STATUS

It might be very pertinently asked at this stage as to why the physiology of health and its gradation in different levels have not been studied inspite of the rapid progress made in the subject of human welfare by eminent scientists. The reasons which may have been responsible for such a state of affairs deserve to be discussed at some length. For far too long, it had been taken for granted that as long any person was not actually ill no body need worry about him. Very probably it was considered too vulgar or low to bestow a thought on the implications of well being in the human frame when the medical profession, was too busy in the sacred duty of relieving bodily distress of their patients and the physiologists no less occupied in revealing the mysteries of the different organs, tissues and enzymes in the body. Both these groups of scientists each sitting in their own set of rigorously isolated ivory towers were engrossed in their comparatively limited spheres of work, and evidently satisfied with their respective achievements.

It must however be understood that the clinicians and the physiologists are not the only groups of scientists who are to be held responsible for not making serious efforts to define or to study the phenomena of 'health' as a positive attribute. The workers in the field of public health cannot escape their share of liabilities. But every body will agree that an epidemic of Cholera, Plague, Smallpox, Malaria, Typhoid or Dysentery often appealed far more strongly to the imagination of the employers of the health worker and the public he served than an incidence of a lowered state of health or sub-nutrition in any community. Indexes for different grades of health could probably have been evolved earlier if the workers in the spheres of human physiology and public health had realised that they had a common objective, and established a liaison to study the phenomena of health. In the teaching institutions, however the professors of Physiology and Hygiene had very often little scope for contact with each other in the sphere of their academic duties. It would not be irrelevant here to take note of the fact that Hygiene or Public Health has all along been treated as a minor subject in the medical curriculum, and physiology has suffered from the disability of being a pre-clinical subject.

Another major factor which might in all possibility have retarded the development of the concept of health as an individual entity, was the rapid progress of specialisation within the subject of Physiology itself. Specialisation must necessarily lead to isolation of thought and narrowing down of the range of intensive studies and research. The inevitable result has been growth of specialists on each of the different aspects of physiology, of the human organism. Consequently in the strong spate of a specialisation though rapid acquisitions to the store of fundamental knowledge was made, the basic fact, that *human organism is not just a conglomeration of different tissues, fluids, and organs* was overlooked, or anyway crowded out of the main stream of active thought of both medical scientists and pure physiologists. Once in a while people did complain over the paradox that whilst most of the owners of automobiles, sewing machines, and typewriters periodically sent these mechanical contrivances to the workshop for overhaul and repairs with a view to enhance their usefulness and prolong their life, such owners themselves rarely consulted doctors unless they were actually ill. Evidently it was not fully realised by the protagonists of such a thought that in the absence of requisite knowledge on the physiology of the organism in its different degrees or grades of health, such visits of apparently healthy individuals to their attending physicians would have led to the embarrassment of the latter, without any benefit accruing to the well intentioned seekers of health.

EMERGENCE OF NUTRITION AS AN ENTITY

The popularity of the cult of 'positive health' in the domain of preventive medicine was very greatly enhanced owing to the conception and development of nutrition activities with renewed vigour each time, after the three successive cataclysms within the living memory. The first world war, the economic depression of the thirties and the second world war, have made us all realise the importance of health as an entity, a positive attribute, and the extreme necessity for such a concept. All physiologists would perhaps agree to the statement that "there is no other single factor so important to the achievement and maintenance of health as is nutrition." Though the concept of nutrition as a separate entity is barely thirty years old, yet the enthusiasm displayed by its votaries and social workers on the subject, is unique. The pediatrician, the clinician, the physiologist, the biochemist and the public health specialist have made voluminous but useful contributions to the subject. But here again, the human organism has not often been regarded as an integrated whole, though such a precious thought was not spared by the nutrition workers in the researches on better crop production and improved live-stock breeding.

Curiously enough, discovery of the formulae of the chemical entities known as vitamins, their isolation from biological material, their synthesis in the laboratory or in an industrial scale, their behaviour in the natural food stuffs during processing, their application in the cure of so called nutritional stigmata, or their relations to certain bodily functions, have appealed more to the imagination of the scientists and to the lay public alike than the study of the technique for evaluation of the nutritional status in individuals. One very likely reason for this indifference was that investigations of such a type needed elaborate planning and collaborated pursuit of the problem, necessitated by the extreme powers of adaptability exhibited by the human organism in modifying the different physiological functions, under the influence of varying environmental conditions and intake of nutrients. Another inherently disquieting factor was that human beings were not just the type of organisms one would welcome for experimental studies. There has been such a mixture of human races since the first appearance of man on our planet, that it has totally ruined the cause of the students of nutritional physiology in certain aspects. It is extremely difficult to find a sufficient number of people with identical characteristics to serve as experimental subjects, or with the possibility of their organic physiology behaving in the same uniform way as individuals from an inbred white rat colony would do. The climax in this tragedy is that with human beings profound differences are often noticed between offsprings even of same parents. Heredity factors will very likely cause such a confusion until such time as the 'New Genetics' cult of Lysenko be satisfactorily proved, and accepted by the various States for regimented production of human communities purely in the interest of experimental scientists. One other reason why experimental physiologists preferred the white rat or other animals to man was, that the effects of diet or change in environment are felt slowly by human subjects. The observer lives with his subjects in the same rythm of life, and consequently is barely able to complete any long term investigations which may have a bearing on the stature, health or organic efficiency of the offsprings of the subject. But the limitations enumerated should not be considered adequate enough for feeling shy of humans as experimental subjects. Finally there has also been a lack of comprehensive plan on the study of the nutritional physiology of man and absence of collaboration between the workers on the different aspects of the subject.

STUDIES IN PHYSIOLOGY OF HEALTH

Prior to the present decade one was not aware of any concerted, comprehensive, or co-ordinated efforts having been made to study the physiology of health and well being, though it could not be truthfully stated that no knowledge whatsoever was available on the subject. From time to time attempts were made to study the physiology of health in its such special aspects as were of particular interest to the investigators concerned. Most of such studies were undertaken in connexion with the employment of workers in the industries with a view to create better conditions of labour which might ultimately lead to increased production, lessened expenditure on illness of workers, and reduction of financial loss consequent to preventable absenteeism. The researches carried out at the Kaiser-Wilhelm-Institut feur Arbeitsphysiologie in Dortmund or under grants from Industrial Health Research Boards in some of the industrially advanced countries fall under this category. The emergence of the concept of nutrition and its acceptance as an integral part of health work in the early thirties stimulated thoughts on health. The existence of large groups of population in the borderland between health and disease was forcefully brought to the notice of the medical profession and laymen through the efforts of the nutrition scientists. Vitative virtues of the vitamins vaunted in the press caught the imagination of not only the lay people and social workers but that of the medical profession also. The craze for medication with vitamins have in all probability resulted in good dividends to shareholders of manufacturing concerns, but it has made even the lay man realise the possibilities of the health of an apparently healthy person being improved. The pioneer efforts of a few scientists to study the relation of health, well being and disease at the Peckham centre deserves a mention here. This venture was started in the late thirties and is reported to be still in operation. It seems justifiable to presume in the absence of detailed knowledge that in an individual free from recognised clinical signs of diseases, the standard of his nutritional status is almost synonymous with that of his health.

Since July 1940, a sub-committee on Medical Nutrition was created by the National Research Council of the United States of America, and serious efforts were made by at least one country to study the influence of nutritional factors on health and efficiency of human organism. Elaborately planned and statistically designed investigations were carried out with healthy human beings as experimental subjects. Special mention may be made in this connexion of the studies on the physiology of experimental starvation for 24 weeks, and on the subsequent rehabilitation of 36 healthy young men at the University of Minnesota. Studies on the conditioning of the human bodies to withstand the stress of abrupt starvation were made at the University of Tennessee. Other studies comprised the determination of the magnitude of losses of water soluble vitamins and minerals in the sweat under simulated tropical conditions, and the effects of dietary factors on the ability of men to withstand repeated exposures to cold at the University of Illinois, investigations on the physiological mechanism regulating the body temperature of men living in colder conditions at the University of Cornell, assessment of dietary protein requirements of men in active and sedentary pursuits, as also the effects of variations of vitamin C intake on the well being and physical fitness of manual workers at theHarvard Fatigue Laboratory, and researches on the appraisal of physical fitness and working ability of young men at high altitude and particularly in relation to the intake of nutrients of Northwestern University. The physiological relations of healthy individuals to their environments in terms of their tolerance to heat and cold, acclimatization, the relation of nutrient intake were also studied by research units deputed from universities during army manoeuvres. One of the salient features of the studies enumerated was, that the researches were sedulously pursued as problems on national health, The human guineapigs in all these studies are reported to have willingly submitted to the rigorous regimen needed for such studies, and most of all, to live for prolonged periods on prescribed and limited intake of food. The fact however can not be overlooked that such extensive studies were carried out during the expediency of war, and not primarily designed for evolution of yardsticks to evaluate the level of health in an individual or a community. Nevertheless, the data collected and records of observations made are likely to make material contribution to our knowledge on the physiology of positive health.

During the war years and even now some amount of work on diagnostic methodology, particularly in relation to avitamanosis, was and still is, being carried out. The data collected at the various prisoner-of-war camps are likely to be of help in making a choice for the physiological indexes that may be used for assessing the levels of health and nutrition. One is looking forward in this connexion to the publication of the observation made by a special team of the Medical Research Council of Great Britain which was deputed to study the incidence of lowered nutrition in Wuppertal of Germany. The experience of the Nutrition Survey units attached to the Allied Control Commission in Germany, if it be published, may be found useful. A comprehensive and critical review of the data collected in all the investigations referred to, by a group or groups of experts is an essential preliminary for indicating lines on which future studies and observations are to be made by the scientists engaged either in laboratory practice, or in field work with particular reference to nutrition. Public Health scientists associated with nutrition surveys have a special responsibility in the matter as evolution of reasonably precise indexes for the appraisal of the levels of health would bring more advantage to their professional work than to that of anybody else. They will have to secure ardent collaboration of physiologists and biochemists to achieve any degree of success.

WHAT CONSTITUTES HEALTH?

It has already been suggested that in individuals free from any recognisable disease the state of health and physical fitness is ordinarily not different from the state of his nutrition. Mere freedom from disease and the possession of, a good set teeth, a healthy skin, bright eyes, proper redness of mucous membrane, faultless auditary ability, developed musculature, the presence of adequate subcutaneous fat under the skin and such other external signs do not imply that a person is in perfect health. Besides the physical signs enumerated, any person claiming optimum health should be able to perform all bodily movements without any distress, possess the capacity to work for fairly reasonable period of time without diminished efficiency, and further, be able to stand the stress and strain of sudden change in environment. Consequently there can never be devised one fool proof, single yardstick for assessing the levels of either health or physical fitness. Ordinarily in human individuals the important criteria to be judged or assessed may be conveniently discussed under the items: physique, organic efficiency and motor fitness.

(*a*) Physique

Evaluation of physique primarily takes into account the impression that any observer may form on the general appearance of the subject under investigation, followed by a systematic examination of the size of the body posture, all round muscular development, chest and abdominal girths, major joints, proportions of bones adipose tissue and muscle in the frame, as also the weight of the subject in relation to his height and preferably to his age. The importance of physique in the determination of the state of health and nutrition came into prominence soon after the first world war. The American War Relief Commissioners and Quakers desired a rapid and objective method for selecting malnourished children for distribution of supplementary foods. In the absence of any reliable yardstick, ratios of various physical measurements which were devised to express body build and physical fitness towards the end of the last century, were taken up avidly by the workers in Vienna and elsewhere to measure the state of nutrition. Anthropometric indexes such as those associated with the names of Quételet, Livi, Pignet, Pirquet and others have been advocated from time to time but so far have not been proved to be either reliable or satisfactory. Even the A.C.H. index which was suggested by the child health experts in U.S.A. after considerable investigation and trial has proved to be of no value by workers [10] & [11] in India. Consequently, inspite of its obvious limitations, the assessment of weight is still regarded as a sheet anchor for evalution of nutritional status. A solitary observation on weight may have little or no value, unless the norms for height and weight figures applicable to the particular group of population under investigation be known or established. But a series of periodical weight averages for any particular group of population does yield useful information as to whether the nutritional state of that particular group is improving or otherwise. The weight averages for different groups of population were being used as a criterion of health status by British and American units in the occupied zones of Germany and Austria after the second world war.

Wetzel[12] has in the recent years evolved a grid technique of appraising body build and the development of each child during the 19-12 years period of school going age. The grid technique should be viewed differently from other indexes of health because it estimates a dynamic state of nutrition instead of the other measures of a static type referred to earlier. This technique, it has been claimed, would be liable to detect any deviation in the developmental rate and nutritional status, which are presumed to be indentical, of the child under investigation. For each subject, channels of constant physique is formed and at about the age of 6 years and never later than 8 years, thenceforth development continues along an established channel. The degree of inclination of the developmental curve or channel is said to give a measure of the nutritional status, and children deviating from the normal growth pattern can be more easily picked out than is possible by any other method. But the record on the grid cannot predict whether the deviation is of a temporary nature or the duration thereof and if the child is likely to recover its normal rate of growth. Further the grid, cannot indicate the causes that may be responsible for the deviation from normal growth. The point which should not be lost sight of in this connexion is, that there may be fluctionations during the growing period in the life of a child, and as such the observations on the grid system should be extended over a sufficiently long period. Anyway the reports received are not discouraging and deserves a trial at the hands of nutrition workers in this country.

A mention may be made here in this connexion of another index originally devised by Tuxford in 1917 after an examination of 500,000 elementary school children. The index was subsequently modified by the author in 1939 and again in 1942. It is a ratio of weight to height graduated in relation to age. It may have been useful for London school children but evidently of little use outside Britain for certain reasons. Anthropometrical studies have been made particularly in France, Italy and U.S.A. about the determination of body types and their ratings with implications of each type on general health. The main categories of the somatotypes are, Ectomorphs, Mesmorphs, Endomorphs and Medials with combinations of one type with the other. But the technique of somatoscopic classification and rating has to be considerably developed to attain that degree of precision, which its advocates claim, in the appraisal of health levels, and in the accurate determination of each type particularly of mixed ones.

(*b*) ORGANIC EFFICIENCY

Till about three decades ago the degree of health and fitness was judged solely by some anthropometric index related to the height and weight and the performances of the subject with a dynamometer. The basic fact that the firmness of the grip recorded on a dynamometer or an endurance test on a cycle or any other mechanical gadget depended to an appreciable extent on the skill of the performer was either not fully understood or was ignored by the investigators. Similar remarks apply to other tests of performance in the assessment of fitness such as the duration of the period for which the subject can suspend himself with his grips fixed on to a horizontal bar. Even if the question of practice and skill did not come in and interfere with the results, it stands to reason that the muscular prowess of one group or a few groups of muscles could hardly be accepted as an index of fitness of the body as a whole.

Quite early it was recognised as a principle in physiology, that physical exertion puts a strain on the mechanism of circulation and respiration before it can cause exhaustion in the voluntary musculature. Studies in the implications of functional heart test were started in Britain more than 30 years ago, and the importance of recorded differences in pulse rate in recumbent and erect posture and of the rate of recuperation in the pulse count after prescribed forms of exertions was taken notice of. Schneider Index was developed later in the U.S.A. on the above principles, and subsequently adopted by the army and the navy there. But recent work has indicated certain limitations to the test. The test which consists of climbing 5 steps on a chair in 15 seconds under standardised conditions, has been recorded to be lowest after heavy meals and after exhaustion due to overwork, but as the body recovered from fatigue the index rose. But the index does not fully express the power and strength of the subject. The Harvard Fatigue laboratory had developed a 5-Minute Step Test on to a 20″ bench in response to the need for a simple criterion to assess the integrity of the circulatory apparatus. For various reasons the test has not been found to be acceptable to the degree one had expected. The fact is well known to the physiologists that more strenuous the exercise more reliable is the pulse rate recuperation test. But organic efficiency cannot be judged through the performance of the circulatory mechanism alone, though it may be regarded as a major contributory factor to the state of fitness. For a large number of years the vital capacity has been enumerated as an index of organic fitness. It need hardly be emphasised that in major affections of heart or lung the vital capacity is considerably lowered. But in interpreting the results of vital capacity test the facts should not be lost sight of that the vital capacity depends to a very great measure on the integrity of the muscles of the chest and abdomen as also that of the diaphragm and can be increased by practice. Further it is doubtful whether differences in Spirometer readings of vital capacity figures between healthy individuals adjusted to surface area, height weight, temperature etc., would ordinarily be of such a magnitude as to permit of indicating the actual differences in the organic efficiency. Of the other tests for respiratory fitness one may mention of Flarimeter Breath Holding Test and maximum expiratory force recorded in blowing against a mercury manometer. But the latter test is, again, a probable index of performance of the abdominal muscles.

The heading 'organic efficiency' has been used in a wider sense and is meant to include the degree of efficiency or performance of other tissues of the body apart from the fitness of the cardiovascular and respiratory mechanism of the body as a whole. The fact cannot be ignored that the total efficiency of any organism depends not only on the performance of its different organs but also on the condition of its tissues and body fluids. Of all the fluids in the body, blood is probably the most important one, and as such assessment of some of the cardinal constituents in a sample of blood may very likely indicate the state of health of the subject. Haemoglobin and protein are the two important components of the blood which deserve our attention, in this connexion.

The report of the Committee on Haemoglobin Surveys 1945 is an interesting document[13] which sums up the knowledge on the technique of surveys. The report, apart from anything else, has proved the absolute necessity for standardising the methods of collection of blood and the technique for estimation of haemoglobin if the results are to be made comparable. It is but logical that laboratory and other methods used for appraisal of health levels should be free from the pitfall of personal bias, as far as this be humanly possible. According to this Report actual readings between skilled observers may vary from 10 to 14%. Further, personal variability ranged from a coefficient of variation of 1.02 percent to 6.90 percent. Another point of interest is that though colour matching by the naked eye in the technique for estimation leaves enough room for personal bias in the observers, this disability cannot be eliminated by photoelectric colorimeter technique.

Concentration of protein in the serum or plasma has been tried as an index in the evaluation of nutritional status on large scale enquiries. Van Slyke's copper sulphate solutions of different density and a relative density gradient with bromobenzene and paraffin have both been used in large scale surveys by different groups of workers. But it has not been clearly established as to how far the protein concentration can give a definite indication of the state of health or nutrition. Theoretically the logic behind the test appears unassailable, but a review of the observations on estimation of serum protein concentration that have been carried out, indicate that conflicting results have been reported by reputed observers. Keys *et at* [14] have found that serum protein content was barely reduced even after protein undernutrition in subjects led to oedema. The work carried out in India [15] also supported such a finding. Studies on albumin-globulin ratio in the serum have not been convincing either.

From time to time attempts have been made to correlate nutritional status with concentration of some of the vitamins in the blood and other body fluids. A special mention may be made in this connexion to the recent study carried out under the auspices of the Medical Research Council in the United Kingdom on the vitamin A requirements of human adults.[16] Th experimental subjects in this long term investigation consisted of twenty men and three women and they were put on vitamin A deficient but otherwise fully balanced diet, till vitamin A deficiencies were manifest. Except that the value for the carotenoid content of plasma of the subjects dropped rapidly at the beginning, no other consistent changes which could be ascribed to vitamin A deficiency were observed, during the first eight months. After this period however the plasma value for vitamin A started to drop. Four of the subjects did not show any signs of deterioration in rod threshold or cone-rod transition time or in plasma value for vitamin A. In great majority of clinical examinations no significant difference could be noticed between the Vitamin-A-deprived and non-deprived group or in the same person before and deprivation of vitamin A. "This applied to the biomicroscopical appearance of the cornea and conjunctiva, the blood picture including platelet counts, gastro-intestinal abnormalities and the incidence of colds and coughs. The only signs and symptoms which seemed to be commoner in the deprived group, though their significance were doubtful, were dryness of the skin and eye discomfort. Audiometry, however, showed a worsening in the deprived group."

Of the different vitamin concentrations that have been studied vitamin C stands supreme probably on account of the ease with which this vitamin can be estimated in the biological material. But not many extensive studies on plasma concentration of vitamin C have so far been made, and it has been observed that increased vitamin C intake raises the plasma concentration level, though the value is variable depending on the seasons of the year. The present consensus of opinion is that ascorbic acid concentration in the leucocytes affords a better index of reserve in the body than its concentration in the plasma. There is a possibility that estimation of serum phosphatase may help materially in determining early stages of rickets but it is very difficult to prophesy how far this index can be of help in grading states of health and nutrition in subjects free from the possibilities of rickets.

It is yet too early to offer any comments if the concentration of the different complexes of B group of vitamins is likely to afford any clue to the nutritional status of invidvals in apparent health. The relation between the blood concentration of any one vitamin with the state of health or nutrition has yet to be established, and the approach to this problem in the existing state of our knowledge can never be too cautious. The results of saturation test with vitamins may serve as a more useful guide to the state of nutrition, than either their respective concentration in the blood or excretion in the urine. Earlier in the text enough evidence has been adduced to invalidate the reliability of so called signs avitaminosis such as phrynoderma, xerophthalmia, angular stomatitis, glossitis and others, as the sole indexes for rating of over all nutrition in a subject.

(*c*) Motor Fitness

In the assessment of motor fitness strength is an important criterion. Since the time the French anthropologists invented them about 250 years ago, the strength dynamometers are still being used to measure the state of physical fitness. Absolute muscle force of any human subject cannot be assessed because no one muscular action of the human body can represent the total body strength, and the internal and external leverage action of the body cannot be excluded during the contraction of any group of skeletal musculature. Consequently dynamometer readings are taken of the right grip, left grip, leg lift and back lift on the two types of dynamometers available for the purpose. The term motor fitness is being freely used in American literature since the beginning of the second world war. The United States Army, Navy and Air Force have prescribed the indexes such as 'pull-ups', 'Sit-ups', '30c yd. shuttle run' and a few others for assessment of motor fitness. Weight lifting, throwing of the discus, high jumps, long jumps and other physical feats are also demonstrative of motor fitness or bodily strength, but their usefulness in the evaluation of the state of health of large population groups has yet to be proved. Finally the degree of performance in each of feats mentioned above can be improved as a result of special training and practice and individual or maiden performances of the untrained do not often indicate the degree of fitness.

For performances associated with motor fitness next to strength, endurance is likely to be presumed as the most important factor. But physiologists would agree that the power of endurance which an individual can exhibit depends to a considerable extent on the integrity of his respiratory and cardiovascular mechanism as also on his neuro-muscular co-ordination and training. Consequently for reasons discussed already it is doubtful if tests for endurance as ordinarily envisaged and practised can hardly be helpful as a reliable index. In planning investigations on motor fitness it should be remembered that there are two aspects of the problem. The first one is to prescribe or determine the minimum limits of certain performances which may be used to screen out recruits from joining the army, the heavy industries or occupations associated with stress and strain or hazards to life. The other aspect of the study is to find out which of these indexes may be used as a criterion to determine the grades of health or nutritional status, and finally to establish forms for the different grades.

CLINICAL RATING

No review, of the knowledge on evaluation of health status however brief, can be complete without a reference to clinical examination of the subjects. Clinical rating has been used extensively in almost all the countries of the world for large scale surveys of population groups particularly in the routine examination of school children, entrants to all the public services and defence forces and more recently in all nutrition surveys. In school medical examinations the children are ordinarily classed into three or four groups such as 'good', 'fair, 'poor' and 'tolerable' etc., by naked eye clinical examination. It is difficult to controvert the fact that even some of the best examiners, themselves being good clinicians, have differed in their opinions regarding the rating of a small percentage of the total children examined and that some of them have differently rated the same subject if he or she was presented for re-examination before the identical examiner after some lapse of time. The reason for such controversial or contradictory findings is not difficult to comprehend. The differences in opinion and anomalies arise in connexion with the rating of such children who happen to be in the borderline of two adjacent grades. Incidence of such an unavoidable, explicable and possibly pardonable error in obiously small percentage of cases should not invalidate the whole of the data or observations.

In their attempt to be more precise and quantitative in the clinical rating of children various schedules of enquiry have been devised from time to time by several groups of investigators. It may be of interest to nutrition workers in India to know that Professor G. Sankaran of Calcutta had long before any of the others elsewhere, devised a score card schedule of enquiry for rating the state of nutrition in children. Subsequently the score card technique of nutrition rating has been accepted by the Section of Nutrition in the United States Public Health Services[17]. Similar cards have also been used in the Oxford Nutrition Survey omitting the technique of scoring. As a matter of fact the point in favour of scoring is that it helps in summing up the results of observations in terms of measurable and comparable quantities. The Nutrition Advisory Committee of the Indian Research Fund Association, have accepted Professor Sankaran's Score Card with minor modifications and recommended its use in routine nutrition surveys in our country. But the argument against score card, which it is difficult to refute is, that the different variates or the items for examination have been weighed equally in the total summation of scores, whereas they may differ individually in their implications on the health or state of nutrition. Supplemented by laboratory findings the clinical rating has a definite place in the appraisal of nutritional status.

One can easily imagine of instances when any subject who may have scored high marks in tests for physique, efficiency and fitness being graded to a lower category simply because he has exhibited the touch of a clinical stigmata, either in the lids of eye or in the forearm. But the implications of appreciable lesions caused by deficiency conditions even in apparently and otherwise upgraded subjects cannot be ignored. In such subjects the reserve accumulations in the body might have been adequately compensating against any effective or demonstrable ill health. It would be logical to presume that in persons rated to possess optimum health the body should operate with a cumulative deposit account and not on a diminishing current account of bodily reserves. Further it is not difficult to imagine that in the daily physiological operations of the organism if the process of withdrawal of reserves is not halted, the body mechanism will no longer compensate when the reserve store is depleted and disease would result. Consequently in an overall estimate of bodily health clinical stigmata, howsoever small, may have its significance the magnitude of which is not known.

SUGGESTIONS FOR FUTURE ACTION

The primary issues that emerge from the review of health and fitness made at some detail are:

(*a*) A critical study has to be made at the first instance of all published data that may have a bearing on human health. The bran and chaff have to be separated and salient facts that might emerge have to be taken sufficient notice of. And in the light of the above studies definite lines on which investigation on the physiology of health can be carried out in the near future will have to be indicated.

(*b*) Important criteria for assessment of the standard of health, physical fitness and nutrition have to be established. Further, the grades or categories of each of these phenomena have to be defined with a certain amount of precision.

(*c*) Conditions have to be created and facilities afforded by the authorities concerned, for studies on the physiology of health.

It would be futile to pretend that the issue raised are very easy of solution. The difficulties in all their implications may appear formidable and depressing, but they should by no means be considered insurmountable. Sincere and effective co-operation between different groups of research workers in the same country and on certain issues between such workers of different countries will be necessary, in addition to more than usual earnestness on the part of the physiologists and health scientists, to solve the problem. It is needless to add that adequate resources should be made available to the various centres of study for the purpose. If magnetic mines were invented and used by the enemy in the last war, the mine detector could be brought into actual operation within a few weeks with the aid of science. Application of Haber's process for large scale manufacture of synthetic fertilisers, development of Radar and industrial production of penicillin are but instances of achievements made because of the strong will behind each of the projects. Both the world wars and particularly the second one have proved beyond all doubts that given the financial opportunities and time, all problems for conquering nature and environments can be solved with the aid of science.

The problems of health dealt at some length in this address is not confined to one country or a group of countries though the incidence of lowered health and sub-nutrition is very high in certain parts of the world. The World Health Organisation can take a lead in this matter for reasons more than one. The Technical Commission of the Health Committee of the now defunct League of Nations had amongst others drawn up a report on physiological basis of nutrition when the world opinion on the subject was far from being unitary. This Commission consisting of international experts had also from time to time made their suggestions pertaining to the various problems on Nutrition. The World Health Organisation would earn the gratitude of many if they in the first instance appoint an *ad hoc committee* or commission for wading through the records of all investigations having a bearing on the physiology of either health, or fitness or nutrition that have been carried out in the past. The Committee can also indicate the lines on which further investigations are to be pursued in all out effort to define each of the phenomenon and the various categories that may have to be established. The World Health Organisation may subsequently initiate and subsidise a planned research work on the subjects in the different countries. It is but reasonable to presume that the organisation in its professed object and efforts for creating better health conditions may take a favourable view of the points raised.

The different scientists engaged in investigations on the physiology of human organism and his welfare in each country should establish a closer liaison between themselves and collaborate in their pursuit for studies on health and health status. Stimulation of thought on the impact of social and economic conditions on health have led to creation of Chairs on Social Medicine in the recent years. Studies on physiology of health is no less important and the departments of public health in the universities and teaching institutions can with advantage take to this type of work jointly with the departments of physiology.

In view of the national importance of the subject it is imperative that adequate facilities be made available to health scientists in our country and proper environment created. The existing arrangements for teaching of Hygiene in the medical colleges in India leave much to be desired. Hygiene is still regarded as a minor subject and medical undergraduates cannot be blamed if they carry an impression that the subject is of very little consequence in their career except for passing the qualifying examination. In most of the teaching institutions the Section or Department of Hygiene consists of a teacher designated as professor or lecturer and possibily of a non-technical person in addition, who may be appointed as care-taker of a few exhibits or models on public health. Unlike the heads of departments for other subjects in the medical colleges somebody holding a whole time appointment in the local health directorate is often saddled with the additional duty of teaching hygiene to our undergraduates.

In all the other departments of teaching in the medical colleges, a man can work his way up adding to his knowledge and experience from the post of a Demonstrator to a lecturer, a Reader and finally to a full fledged Professor; but the section of Hygiene affords no such change because of its being a department, if at all, manned by one person. The professorship of Hygiene or Preventive Medicine should be made a whole time appointment in each of the medical colleges in this country and the emoluments fixed at such rates as would ensure recruitment of properly qualified persons. Adequate staff, equipment and facilities for research work should also be provided for. Concurrently with the creation of proper sections for teaching of hygiene, the facilities for research work in the departments of physiology should also be enhanced. Earlier a reference was made to the fact of physiology being treated as a preclinical subject.

I can do no better than quote Professor A. V. Hill[18] in this context: "The pre-clinical sciences are the basis of the scientific study of medicine and of what is now called clinical science. If pre-clinical sciences are weak it will almost inevitably follow and it has followed in India that clinical research and the standards of higher medical thought and education will be in a bad way". This point has also been clearly enunciated in the report of the Goodenough Committee on medical education in Britain and published by H. M. Stationery Office in 1944. It is a happy augury that our Minister for Health, the Hon'ble Rajkumari Amrit Kaur, in her address to the Medical Council of India about three months ago has stressed the desirability of having 'at least a nucleus of full-time professorial staff who are disallowed private practice' in 'the different departments of a Medical College' and has further added that 'every department of a college should be encouraged to promote research as an essential part of its teaching'.

Last, though not the least is the problem of recruitment of suitable personnel to carry out researches either in the universities, science colleges or medical institutions. It is a regrettable fact and has also been ably pointed out by Professor Hill in his report quoted above that "scientific service under the Government is not in general comparable in pay and status with the civil service or such as to secure the appointment of the ablest man or to give them the best opportunities for developing and utilizing their talents." One cannot blame young Indians with intelligence,, skill and inititative to take to the Indian Administrative Service or a similar non-technical service with good pay and prospects in preference to scientific appointments in the medical schools, colleges and universities. It would not be in the best interests of any country to create such conditions of employment as would ordinarily detract the top ranking university students from the pursuit of science mainly due to economic reasons. The French Scientist Jean Perrin in a recent publication, has lamented[*] over the fact that no country has so far made a serious attempt to ensure that those gifted with aptitude for scientific research do not find themselves kept away from it solely through the want of material necessities in life. According to him we have lost many men of genius and that our present existence is surely poor and miserable compared to what we could have achieved even now and if such research workers were able to develop their talents fully.

The Government of the United Kingdom have, as a result of their experience during the last war, resolved that the conditions of service for scientists working for the State shall be such as to attract into the civil service scientifically qualified men and women of high calibre and to enable them after entry to the best use of their abilities. And about four years ago terms and conditions of the Scientific Civil Service were formulated and published[19] to attract suitable recruits. We fondly and earnestly hope that the people and the Government in our country would take note of the hard facts and try to create conditions which will ensure the recruitment of the very best material available from the universities not only to administrative services but to scientific appointments as well. Let us hope and wait.

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[*] 'Il semble donc insensé que les diverses nations n'aient fait jusqu'ici aucun effort sérieux pour que ceux qui sont doués pour cette recherche ne s'en trouvent pas écartés par des nécessités matérielles. Nous avons ainsi perdu tant d'hommes de génie que notre existence actuelle est certainement pauvre et misérable à côté de celle que nous ménerions, aujourd'hui même, si ces chercheurs avaient pu se developper'.

REFERENCES

1. Lovat Evans. Principles of Human Physiology J. & A. Churchill London. 1947.
2. Mitra, K. (1943 & 1944) Unpublished Reports to I.R.F.A.
3. Simpson, J. (1946) Lancet i, p. 959.
4. Burgess, R. C. (1946) ibid ii, p. 411.
5. Mitchell, J. B. & Black, J. A. (1946) ibid ii, p. 855.
6. Walters, J. H. & Rossiter, R. J. (1947 ibid i, p. 205.
7. Special article, (1948) ibid ii, p. 228.
8. Adcock E. W. et al (1947) Jour. Hyg. Camb., 45, p. 65.
9. Burridge, D. H. D. (1949) Jour. Roy. Army. Med. Cor. 92, p. 77.
10. Aykroyd W. R. & Rajagopal K. (1938) Ind. Jour. Med. Res. 26, p. 55.
11. Mitra, K. (1940) ibid 27, p. 887.
12. Wetzel, N. C. (1941) Jour. Amer. Med. Assoc. 116, p. 1187.
13. Committee on Haemoglobin Surveys (1945) Med. Res. Coun. Spl. Rpl. Ser. No. 252 H.M.S.O. London.
14. Keys, A. et al (1946) Science 103, p. 669.
15. Hynes, M. Ishaq, M. & Morris, L. (1946) Lancet ii, p. 590.
16. Vitamin A Requirements of Med. Res. Coun. Spl. Rpl. Ser. No. 264
17. Sandstead H. R. } (1947) Pub. Hlth. Rep. U.S.A., 62, p 1073.
    Anderson R. K. }
18. Hill A. V. (1945) Scientific Research in India. Government of India Press, New Delhi.
19. Document No. cmd. 6679. H. M. S. O. London 1946.

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SECTION OF PSYCHOLOGY AND EDUCATIONAL SCIENCE

PRESIDENT : KALI PRASAD, M.A., Ph.D.

Presidential Address

Psychological Research in India.

Progress of modern science is characterised by the uneven development of its three main branches *viz.,* the relatively high degree of control which physical science has enabled us to acquire over inorganic nature, our still very rudimentary knowledge of biology and the almost complete absence of scientific Psychology and Sociology. The consequence has been that while our environment and mode of life have changed profoundly by the application of physical and chemical knowledge, the human organism has had no time to adapt itself to these changes. There has been a great and growing disharmony between the human organism and the highly complex environment which physical science has fashioned around it. This imbalance between physical and technological development on the one hand and our relative ignorance of the social and psychological processes on the other, is a peculiar incongruity of modern times and unless it is corrected there is hardly any chance of social understanding and human progress. But it cannot be corrected except by a *deliberate* modification of the physical environment. We have to give up the complacent belief of the nineteenth century philosopher in the inevitability of progress; we have learnt through bitter experience how that belief was mistaken. We have seen that left to himself an individual or community, like any organic material, may run wild or degenerate. Progress in social matters has to be striven for and planned as assiduously and carefully as in the world of physical phenomena. For, human nature is not some immutable essence which endures through eternity and which the philosopher may only contemplate; it is a fluctuating dynamic pattern determined by complex conditions of life and nature. But change of human nature and the making of man cannot be possible until social sciences are developed enormously; until we have a scientific knowledge of biology, physiology, psychology and genetics comparable in extent and accuracy to our knowledge of physics and chemistry. Until this is achieved, civilisation will always be exposed to the threat of extinction by the very instruments which scientific technology continuously forges. For man is still unable to appreciate their appropriate use and like a child is inclined to employ the products of his scientific genius for display of his physical prowess and sometimes even as engines for the destruction of society and for his own annihilation. The present emotional make-up of man and the extraordinarily crude and inept forms of his social organisation are such that the dangers of abnormal development of physical sciences would continue for a long time. The danger could perhaps be averted if the emotional constitution of man is understood and reorganised, otherwise the combination of our present ignorance about the mechanisms of human motivation along with our knowledge of physical sciences is bound to wreck the whole fabric of society. The misuse of atomic energy by the scientifically advanced countries of today already bears witness to the enormous powers of destruction which discoveries in physical science have placed in the hands of people who are emotionally and intellectually still at the level of infantile mentality. As individuals or groups of men have not learnt to adjust themselves to their social enviornment because they do not know one another and do not have any clear idea of the meaning and purpose of human existence itself.

Our knowledge of man is extremely superficial and inadequate. The barriers in the way of understanding have been largely psychological. We have not yet learnt how to assess adequately the influence of psycho-biological and psycho-social determinants of human behaviour, nor to appreciate the significance of the fluctuating patterns of our reactions as they develop in a complicated social mileu. The complexity of the human organism with its manifold adjustive and reactive modes of responses has been a challenge to the most discriminating psychological analysis and experiment. The technique of investigating these reactions is so imperfectly developed to-day that we often feel sceptical whether psychological data can be subjected to objective, scientific treatment at all. In this atmosphere of uncertainty, a further cause for alarm has been found in the conflict between contending schools of present day psychology. In the present state of psychological knowledge, however, such a situation is perhaps unavoidable. The conflicts of the rival schools are an evidence not only of the youthful character of this science but also suggest that human behaviour is a multidimensional reality which admits of a number of approaches all likely to furnish valuable clues to our understanding of man. The social sciences have, therefore, a difficult task and in the crisis with which modern civilisation is faced the development of scientific psychology is an imperative necessity; for psychology is the basic foundation of all social sciences. Fortunately, there are signs in Western countries of an increasing emphasis that is now being placed on it. The great volume of literature on psychology and the social sciences and the formation of organisations such as the U N O and the U N E S C O testify to the growing anxiety of modern man to understand man. For this reason the modern century has been called a psychological century *par excellence.*

Unfortunately, in India psychological research is still in its early infancy. The comparative newness of the subject, lack of facilities for experimental work, paucity of competent workers and the poverty of equipment of both teachers and students would possibly explain why no distinctive achievement has been made in psychology in this country. In most universities and colleges psychology is grouped as an "Art" subject and is divorced completely from a laboratory setting. It is taught and read like literature or classical language but without the throughness and critical appreciation normally associated with the study of the latter. The student goes through topics such as perception, memory, feeling, emotion, learning, motivation, conditioning, association, sensation etc., without illustrative aids or statistical data—without knowing the experiments on which work on them is based. Even the anatomy and psycho-physiology of nervous system are sought to be understood without any models, dissections, laboratory preparations and experiments. It is like learning physics or chemistry or biology without stepping tnto the laboratory. Actually the situation is worse, because while no physicist or chemist or biologist would dream working without a laboratory, the psychologist often thinks that since laboratory technique commits one to a particular brand of psychology (such as, for instance, behaviourism or reflexology), one who does not accept this brand is free to develop his psychology more or less independently of experimental and laboratory methods. Sometimes he even boasts of this independence and entrenches in his complacency by the belief that the so-called pattern of pure introspective psychology is quite sufficient to reveal the complex processes of mind and behaviour. While the inevitability of introspective observation in all scientific procedure has never been doubted it is equally obvious that the behavioral situation has so many aspects which lend themselves to experimental study and objective treatment. In fact, the latter approach is so comprehensive that it includes among other things an introspective report and the so-called subjective appraisal of phenomenal experience. The experimental approach is a natural and a logical method of dealing with the date of Psychology as a science. Today it is no longer question of choice: if psychology is to be developed as a science, it has to be experimental psychology in the strictly science sense of the term. And, the little progress that has been made in psychology in modern times is doubtless due to the frank and conscious acceptance of this point of view. It also implies the equally frank and conscious rejection of Pseudopsychological and speculative attitude that psychologists in this country have directly or indirectly brought to bear on the study of psychological phenomena, and this has definitely hampered progress.

The remark may appear to be trite and yet if we examine the matter closely we shall find that it has profoundly influenced our attitude toward psychological research here—Our work in psychology has lacked as much the initial conviction in the relevance of scientific methodology as a persevering faith in a scientific theory as necessery inspiration for the organisation of the data of phenomenal experience. We have neither had the one nor the other with the result that even where research has been attempted much of it has been without design and, of course, without vision. Where a problem has been tackled the method has been imitative or repetitive and the results have been therefore often trivial. No systematic theory or hypothesis in general or applied field of psychology has been developed and in consequence, it has not been possible to make a distinctive contribution in either fold.

Now, there are two fundamental problem in psychological research *viz.*, (1) Constructive effort in systematic and experimental psychology, and (2) research in applied psychology especially in the fields of social psychology and educational psychology. The two problems are bound together so that any advance in one would inevitably influence the other. But it is essential to develop both. In regard to the demand for a theory we may suggest that modern psychology is coming more and more to realise that the concepts developed for instance, by Gestalt Theory provide an adequate basis for understanding at least the fundamental structure of mind and behaviour. In certain fields of behavior *e.g.*. perception, learning, memory, and thought this is already recognised. And as our knowledge of facts in other regions of experience increases, the insight already won will find greater amplification—Meanwhile, we need concepts or rather constructs which would serve to reorganise total fields of experience and make them significant. The system of concepts must be broad enough to be applicable to the most primitive bodily behavior as well as to the emotions, thought—processes, values and social relationships. It must be capable of representing these processes not as single isolated facts but in their mutual dependence as expressions of a concrete situation involving a definite person in a definite condition. These concepts must unify without undue simplification; they must include both person and environment, both law and individual case. These requirements can be fulfilled only if one turns from the prevailing methods of '.abstractive classification" and tries to build 'constructive concepts.' Such an approach would have to be oriented both toward theoretical connectedness and toward concreteness,' that is, it would have to be both constructive and experimental or 'operational' and not speculative and explanatory.

But before such a theory can be understood it may be well to prepare the ground by considering an important change which has come over modern psychology. This may be done, for instance, by contrasting, what has been called the Aristotelian and Galilean modes of thought in contemporary psychology. The distinctive character of Aristotelian science is its appeal to final causes, its anthropomorphic tendency and its *a priori*—deductive method as district from the experimental and hypothetico-deductive approach of modern science. For instance, Aristotelian physics employs normative concepts like 'good' and 'perfect' with reference to circular and rectilinear motions of bodies. For this reason heavenly movements are considered as perfect because they are circular, while sublunar motions, not being so rhythmical, are regarded inferior and imperfect. Likewise, Aristotelain biology uses the concept of perfection or goal and *entelechy* to explain the phenomena of growth and evolution. Every living organism, according to this theory, has tendency to move towards its perfection. Distrubances due to chance make for exceptional cases which must be rejected as refractory. General uniformities and the 'law' constitute the main concern of science; the exceptional and the individual case are treated as deviations from the universal form and as such of no particular consequence.

While physical and biological sciences today have shaken off the Aristotelian influence to a considerable extent, psychology is still under its dominance. The substantial and causal-analytic approach of Aristotelian psychology finds illustration in prevalent distinctions between 'normal', 'abnormal' or 'pathological', 'errors' and 'success'; memory and forgetting etc., as absolute categories. All these are classified according to the value of their *products* rather than that of their *process.* The direction and character of response are supposed to be determined *a priori* by the essence of purpose or 'goal' of behavior-pattern rather than the object and the situation taken as an integral whole. The Aristotelian view stresses the 'historicity' and 'frequency' of a phenomenon; while modern psychology tries to get rid of the historical 'bent' by reference to the concrete whole, the objective process, or, raher the 'process differential', as it has been called. In place of the 'law of frequency', modern science puts forward the principle of 'general validity' which far from considering the exceptional or the individual case as an aberration looks for hypotheses which accommodate it. In place of dichotomies and divisions, a process of homogenisation is aimed at and psychological laws attempt to proceed from the average to the 'pure case'. The contrast is best exemplified by the distinction between class-theory and field-theory. A class concept is primarily based on *a priori* or intuitive ground, independent of individual cases, while a field construct is inevitably moored in the data of phenomenal experience and the dynamics of the situation as a whole. According to the former, particular phenomena derive their significance from the primitive concept which they seek to illustrate and represent; according to the field theory, they are basic to any law of general validity which is impossible to attain without them.

The class-theory is always concerned with the types of phenomena which would exemplify particular cases conforming or belonging to the class; the field-theory suggests logical constructs which are based on the dynamical properties of the experienced situation. 'The field theorist *orders* his experience to these logical constructs.' In so far as his phenotypical experience may be so ordered to these genotypical constructs that he may deduce what his subsequent experiences will be, he considers his scientific analysis successful. Explanation of an event consists in adequately describing the underlying genotype and in seeing if the phenotype (experience or data) may be precisely *ordered* to it. Laws are descriptions of genotypes'. It is here that field theory has a great advantage over the class theory. When the laws (genotypes, underlying dynamics) are sufficiently well known to admit of measurement, the future may be predicted independently of the past. For instance, the law of the falling bodies holds universally even though there are great differences in individual situations of the various objects. But in psychology a law is always difficult to attain on account of genetic, historical and other factors. Thus while physics has already made a transition from the phenotypical to the genotypical stage and biology is making its psychology has not yet made it, though it is on the thereshold of such a change.

This change is already marked in discarding or radically modifying certain traditional postulates such as, for instace, the causal-analytic view, the theory of universal psychical determinism and the overruling unity of mind. These have dominated psychology throughout and are only now begining to be seriously questioned, for it is realised that their uncritical adoption has prejudiced scientific understanding of human behaviour. This is not the place to examine the three concepts mentioned above, but a word may be permitted about the functional-dynamic approach implicit in field theory which replaces them and which would seem to provide a satisfactory basis for scientific psychology. According to this view human behaviour is a complex whole which varies as the total interacting set of conditions change. There is no simple, direct or symmetrical relationship between the stimulus and response such as be expressed in terms of the causal nexus. In actual behavior the physical reality of the stimulus plays an unimportant part: its 'psychological reality' is its most essential aspect. The stimulus situation serves to organise or restatify a behavior-pattern through available energy systems. In this way certain tense psychical systems occur with their own vectors seeking to give direction to an action-pattern in the environmental field. The so-called inner and outer environment are 'charged' by the process itself. But there is a steering of the process by the total perceptual field. A behavior-process is an effect or a resultant of the cumulative operation of various causal factors but is a function of the dynamics of the situation as a whole. When an existing psychical tension—a wish, a need, a half-finished activity etc., finds outlet in motor discharge, a new equilbrium is set up and the objects acquire 'valence' (positive or negative).

These changes in the level of response cannot be explained in terms of the causal-analytic view which is quite inadequate for understanding the *dynamic and fluid* character of response patterns. The reaction field embodies various kinds of stresses and strains where the unity of the individual is no permanent essence but represents only *functional firmness.* The whole process moves in the direction of a state of equilibrium only for the system as a whole. When system as a whole which is dominant at a particular moment may be taken as the basis of the so-called unity; though there are relatively stable systems which dominate the others and give uniqueness and individuality to the whole (as when a complex determines an individual's action patterns to the whole (as when a complex determines an individual's action patterns and colours his memories, thoughts, perceptions and emotions). It is a state of moving equilbrium. But state of moving equilbrium in a system may also involve tension. A system may come to equilbrium in a state of tension as a spring in tension, a frustrated wish, a half-finished activity, and a long-forgotten sorrow. Considerable functional firmness would thus seem to characterise certain psychical systems. The functional firmness is determined simultaneously by the so-called internal and external conditions, or rather by psycho-biological and social-environmental milieu taken in their indissoluble wholeness.

The psychical processes are really life-processes developing in their own life-space; they are embedded in the individual's life in an environment. Life-space would appear to have at least two dimensions; loco-motion and reality-irreality. Behaviour implies movement or ability to make a transition from one sector or region to another in the field of experience. There are barriers and boundaries which are sometimes comparatively inflexible but often they are permeable and permit considerable locomotion within a limited region. But movement may also be one level to another such as when we from the plane of physical reality to that pass the 'irreality or, rather, the reality of psychological domain. A vague fear, a day-dream, a phantasy is generally regarded as less real than action based on the immediate needs of a person. But apart from the fact that actions themselves have different degrees of reality, the images and phantasies may sometimes have a much greater psychological reality than the surrounding objects in the environment. It is common knowledge how behavioral trends are sometimes completely dominated by theses so-called 'irreal' processes. There is considerable experimental evidence to show that the degree of reality is an important dynamic property of psychological phenomena. The various levels of reality may be, however, operative at the same time though in different degrees in an individual. Even when a person has taken flight into phantasy, he is still moored in the 'real' world of physical being. But in extreme cases this influence of one level on the other may be so greatly weakened that there is a split between the two as, for instance, in schizophrenia. Normally, there is a development of life-space to the highest plane of reality as one passes from childhood to maturity. This development is a function of the differentiation of a person and his enviornment and represents stratification of levels of different degrees of reality in the course of experience. How behaviour develops and what events occur would thus depend on the relationship between the different levels and particularly on the directed magnitudes (vectors) in the psychological field.

This dynamic field theory lays the much needed stress on the fluid character of a psychological field where the individual-in-environment occurs as the primitive and irreducible datum of experience. But it requires to be supplemented in an important manner. The behaviour trends of an individual cannot be adequately understood unless the unconscious dimension is also taken into consideration. All normal behaviour in some ways shows character traits which are the socialised residues of infantile psycho-sexual urges. The frustrations of early childhood (including perhaps the trauma of birth itself) continue to colour one's modes of behaviour unconsciously throughout life. The individual overcomes these early frustrations by building up various unconscious mechanisms such as sublimation and reaction-formation. Though the normal adult succeeds in adapting his libidinal and aggressive urges to the demands of society, he still carries these early strivings with him in his unconscious mind. When they are strongly reactivated through some events of adult experience, they lead to distinct forms of neurosis, otherwise, these id forces continue to express themselves in socially acceptable behaviour. The normal and the neurotic, the genius and the psychotic, alike represent attempts at resolution of unconscious conflicts and frustrations seeking the most efficacious and economical symptomatic-behavior in varying situations of life. The two urges- Eros and Thanatos, life and death instincts which may be probably aspects of some even more primitive tendency lie at the base of the unconscious and keep continually asserting themselves. Whether the one is more dominant than the other, whether the death instinct is being continually thwarted and neutralised by erotic urges until it finally triumphs are questions which tend to take psycho-analysis into the domain of metaphysics into which the psychologist can ill-afford to stray. Nevertheless, their fundamental ambivalence is a dominant characteristic of all behaviour and supplies its deep-lying motivations. Thus, in view of its pervasive character the dynamics of the unconscious would be essential for formulating any field theory of mind or behaviour such as the one we have been attempting to present.

The field-theoretical approach is specially suited for experimental work. It evidently provides an adequate basis for the development of psychological research because it starts with no *a priori* assumptions concerning the character of the behavioral field. It employs phenemenological method in objective observation of behavior-data and proceeds to view them in a complex psycho-biological and social milieu. Under the guidence of this theory research in the various branches of psychology can be developed without the cramping influence of certain pseudo-psychological and speculative ideas such as, for instance the theory of instincts as isolated and inexplicable sources of energy, or the theory of (unchanging) human nature or the mnemic theory of memory or the syllogistic theory of reasoning or the theory of the irrationality of the insane and the child etc. The two fields where research is especially necessary in our country today are educational psychology and Social Psychology. Let us examine briefly the type of work that may be done in these.

Educational psychology has obviously a very large scope with a bewildering variety of problems. But our educational research has to take some of these problems which are in many fundamental ways different from those in Western countries and are peculiar to the conditions in our country. Uncritical acceptance of foreign models will only retard progress and hasty improvisations which characterise so many post-war (and post-freedom) programmes would be disastrous in the domain of educational theory or practice—I may give here in the briefest possible manner schematic description of some of these problems which require detailed scientific investigation. We may broadly classify educational problems under four major heads:

1. Those concerning the individual *i.e.*, the child, his educable capacity his normalcy or otherwise etc.
2. Those concerning processes or mechanisms of educations, like school organisations, curricula, examinations, syllabus etc.
3. Those relating to the determination of the fitness, aptitude, and individuality of the teacher, his emoluments, his economic and social status and
4. Problems in education, its relations to art, aesthetics and culture.

It is impossible to dwell upon all these here. We may single out the first one, *viz.*, relating to the child as the educable (or ineducable) unit. This breaks up to at least in the following four groups of problems.

(1) Problems concerning intelligence testing and mental dificiency or subnormality.
(2) Problems of educational measurement.
(3) Problems relating to measurement of individual differences.
(4) Problems of social adjustment, emotional stress and personality profiles.

Under the first head may be mentioned problems relating to the determination and measurement of a child's intellectual status or mental capacity; his intelligence quotient, correlational studies of intelligence to speed, accuracy Intelligence of Subnormal and gifted children; Racial difference in intelligence; Factorial analysis of intelligence; Intelligence and school marks; speech defects, eye defects; deaf-mutism and intelligence, stuttering and stammering; intelligence and left-handedness; educational retardation. construction of intelligence scales; revision and readaption of Binet-Simon Tests; performance- test for children of high grade and low grade intelligence etc., etc.,

Under the second head may be mentioned measurement of the amount of language development; suggestion effects; effects of hand-writing on grading, correlation between various subjects (*e.g.*, English Mathematics, Science and Languages, History etc.); High School Composition; effect of verbal and written examination, vocabulary and school results; spelling studies. scholastic and general attainment tests; reliability of school grading, etc.. etc.

The third group includes problems relating to measurement of individual differences such as determination of image-type the Eidetic type (B or T type); differences according to age, sex, environment, parental vocation, etc.; hereditary tendencies and traits; mental capacity of twins, comparison with foster children; orphanage children, children brought up in special circumstances (gypsy children, criminal tribes" children, wolf children) etc., etc.

The fourth group comprises problems such as leadership in pre-school children; emotional stability and instability; the psychology of class room, examination room; children's fears; their loves and hates their attitude towards younger and their elder boys and parents and teachers; children lies; studies of certain types of children such as the neurotic type, the pampered type, the obstinate child, the excited and irritable type, the obsessive child, the timid child, the thieving child, the criminal child etc., the child from poor homes, broken homes, the only child, the overgrown and the undergrown child, etc. etc.

Some work has been attempted on some of the problems mentioned above. For instance, intelligence tests, achievement tests, and aptitude tests, have been prepared for certain groups. Certain studies of delinquency have also been made. But all these have been inevitably confined to provinces where they have been undertaken. They have very limited application. We have yet to have a scale of intelligence which would give a reliable measure of the intelligence of children sampled from various parts of the country. Modifications of Binet Simon, Terman-revision, OTIS tets and others have been attempted, but usually they bear strong local colour and cannot be applied to regions where they did not originate. Individuals have very often worked in isolation sometimes even without knowledge of parallel investigations not to speak of any collaboration or cooperation between workers in the same field. The notorious unreliability of age records of children and great differences in the culture and social strata from which they come are such serious difficulties that they have effectively prevented the spread of the mental tests movement in this country. But these difficulties can be met to a large extent by large scale sampling from representative regions and careful adaptation of tests. There are two other ways of overcoming this difficulty: (1) by stressing psychological experimentation and (2) by developing achievement or accomplishment tests in education.

As we know the distinction between psychological testing and psychological experimentation is not absolute. It is true that psychological tests aim at revealing the characterstics of persons while psychological experiments seek to reveal the characteristics of mental processes. But any adequate appraisal of the mentality and personality of an individual would obviously call for an understanding of the nature of his mental processes. If it is proposed to rate him on general intelligence, introversion or interest, the question of what these tests really are is certainly involved; and until it is answered thoroughly satisfactory tests cannot be constructed. Actually the two lines of work are now converging. Workers in the field of psychological testing are becoming more and more concerned with the nature of the processes with which they try to deal. Test data are supposed to throw light not only on individual traits of a person but also on the nature of the mental processes and organisation of the mind as a whole. For instance the factor analysis of intelligence proceeds on this consideration—In this connection Thurstone's factorial study has led to the conclusion that performance on a certain set of tests involves at least seven mental processes—numerical facility, world fluency, visualisation of space, memory for words, names and numbers, perceptual speed, verbal reasoning, and induction. And, as is well known, Spearman holds that most mental test performances demand a general factor which seems to consist of a general intellectual energy. Similiarly experiments on memory, learning, imagery, perceptual acuities, reasoning etc., would undoubtedly help one to asses an individual's mental status, just as test performance on a particular trait would also give a clue to an individual's mentality. Experiments and tests have different purposes and different orientations but they supplement each other and both should be worked together to yield an estimate of a person.

Again, intelligence tests and educational or achievement tests have a great deal in common. While there may be serious obstacles in the way of constructing a national intelligence test today, we can develop achievement or accomplishment tests for school children in school subjects such as reading, arithmetic, spelling social studies, science, geography, languages etc. It is recognised that a well-chosen and diversified set of educational tests measure psychological processes quite satisfactorily—Lorge has shown that the combined standing of a group of subjects on a reading test and an arithmetic test could be undertaken as an index of intelligence much in the same way as any suitable test of general intelligence. But the educational tests must be broad and general in its reference and not too strictly limited to trivial details of a pupil's text book.

Present day curriculum will have to be modified so as to allow room for different type of school books. Educational "Texts are directed not only to the memory processes and information, but to the problematic thinking, the drawing of inferences from data, the application of generalisation to specific problems and situations, study habits practices, appreciation insight etc., "Thus constructed they are apt to stress psychological processes generally and are bound to provide a clue to the understanding of a pupil's mental status.

Lastly, performance tests will have to be used far more extensively than has been done so far. They will appear to have special usefulness in the peculiar conditions of our country. It is true that as a measure of general intelligence they show only medium to low correlation with customary criteria such as results on standard intelligence tests and schools achievement. But where the latter are not available as in our case, performance tests may be the only means of ascertaining mental status. There are a large number of performance tests but they are all based on the three well-known scales *viz.*, (*i*) Pintner-Patterson scale of performance test, published in 1917 and revised in 1937; (*ii*) the Arthur point scale of performance tests and (*iii*) the Cornell-Coxe performance ability scale. Any one of these could be used with necessary modifications and adaptations. Such tests overcome the excessive verbalism of the ordinary intelligence tests and would make it possible immediately to arrive at some psychological estimate of vast populations of children who are illiterate. Also, they make it easier to discriminate between the bright and the dull and the defective. They often have clinical value and may indicate certain type of mental and emotional disturbance. Even though in view of their emphasis upon speed, manipulation, dexterity, neural control, visual memory etc., they embody a different conception of intelligence from that represented in the standard tests of general intelligence, still in the present situation they have unlimited scope and may be recommended for extensive use. When a national general intelligence test is constructed they could be used as a valuable supplement.

We shall now pass on to the consideration of certain important problems which await investigation and research in the field of social psychology. Here the field theory is specially appropriate—as we have said earlier the major problem of mankind is to develop a scientific understanding of the pervasive characteristic of man. The world is full of national and "racial" groups with their distinctive culture and social background. Within the same national groups children and adults are distinguishable on the basis of differing personality patterns. Even when genetic factors are held as constant as possible that is, where there are several children of the same parents in family, children are distinguishable from one another. Children of the same family may vary considerably with regard to intelligence, physical strength, memory, and thinking behaviour, responsiveness to cultural demands etc. The variables are numerous and our knowledge of these concomitant factors which influence personality develompent is quite incomplete. In addition, there are fortuitous circumstances such as the order of birth, changes in family structure, rejection by one or both parents, the number and sex of siblings; the loss of one or both parents, the tribe and class to which one belongs. The situation is further complicated in our country by the rigidity of the caste system to which one is irrevokably born. There is no permeability and locomotion between the caste-barriers and whatever may have been its metaphysical or orthodox philosophy, psychologically and socially the results of the system have been disastrous. Above any other problem this is the one problem which has to be immediately tackled by all the resources which psychological knowledge has placed before us. Legislative and economic changes are undoubtedly required, but the question is fundamentally psychological, *viz.*, that of changing the mind and attitude of our people. That there are bound to be some kind of stratification in all societies is not doubted. But where our stratum in completely sealed of from another it leads to the development of patterns of personality-responses which are basically determined by anxiety, feeling of insecurity, fear, suspicion, jealousy, mistrust, hatred and exploitation. And this just what characterises the caste or the communal mind in our country. Each cast develops, what one might call, its characteristic mental-pattern and behaviour attitudes which have their moorings in fear, anxiety and hatred. These feelings may be rooted in totemistic taboos and traditional beliefs or ritualistic or religious unction and metaphysical illusions. The contents of these feelings includes fear intolerance, arrogance and superiority urge of its reaction formation as extreme submissiveness and wirthlessness and cynical disregard for other groups and classes. As a child the individual belonging to a caste-group grows up in habits of behaviour which later appear as *natural* to the group. It is not recognised that the naturalness of the caste or communal mind is itself a product of long process of socialisation and that if a different mental set-up is desired it has to be worked for from the begining i.e., from the time of the birth of an individual in a familial-social milieu.

In order to achieve this end, field surveys of families have to be undertaken. A study of their customs, beliefs, superstitions, social habits, birth, marriage and death rites, their specific culture trends etc., has to be made. Some of this could be ascertained by carefully devised questionnaires or situation-tests and other kinds of projective techniques. In western countries similiar studies have been undertaken with profit. The following types of work may be mentioned as examples of the lines of research that may be taken up in our own country. Does culture affect Patterns of Infant Behaviour? by Denais; Social determinant of the level of aspiration by Chapman and Volkmann: skin colour judgements of Negro College students by Marks;

social factors in moral judgement by Pigget; verbal stereotypes and racial prejudice by Katz and Braly; hostility and social frustration studies by Sears, Bateson, Dollard, Maslow, Dembo, Lewin etc.; measurement of social distance by Bogardus; social status and child rearing by Ericson; Anti-democratic Personality by Frenkel-Bursswick, Lavinson and Sanford; psychology of rumour by Allport and Postman; war and peace by Kluckholn etc. etc. To these may be added own distinctive problems such as the study of group or caste differences in various psychological dimensions, such as aggressive or submissive characterrstics; religious orthodoxy and strength of traditions or unorthodoxy; social, moral, rigidity or otherwise etc. There are probably characteristic attitudes in certain groups such as may be symbolised by what might be called for purpose of methodological convenience the 'Brahman mind,' 'the Bania mind,' 'the Kshatriya mind' etc., psychology of Indian women; study of the upper and lower middle class; the mind of the rural worker; the urban worker; the psychology of priesthood; the psychology of so-called scheduled caste and the artificially isolated, 'untouchables' and the equally artificially created criminal tribes etc. etc.,

Social reform would be impossible without a detailed and dispassionate investigation into the foundation of our social structure. So far we have had social workers who have brought to bear emotional or romantic attitude on these problems. They have neither had the equipment nor the incentive to study them scientifically. This is perhaps one reason why the remedies suggested have been either too idealistic and utopian or too superficial with the result that the main structure of our society has remained in all its essentials as it was given several hundred years ago. The last few centuries which have seen the rise of Science and the transformation of the western civilisation have largely bye-passed our country which has retained its mediaeval mind and outlook in these modern days. This mediaeval mind has to be re-educated and changed and overhauled. For this we have to develop a technique of *social engineering* based on psychological analysis and understanding. We have to dig up the past and excavate the foundations of our basic culture to seize upon the abiding elements in it. For, we cannot build without utilising certain materials which have been acquired through long process of trial and effort and the travil of experience or which have been obtained by extraordinary insights of the ancient builders of this land. They have to be adapted and refashioned by a process of creative synthesis into a structure which will be suited to present needs and will be responsive to the dynamic rapidly changing world of today. Our culture and our spiritual heritage have a message of peace for the war-torn world of modern man. But it has to be assimilated and learnt by ourselves first before we can play the evangelist of our religious catholicity, and our spiritual granduer. At the same time we have to guard against the very real danger of revivalism and the resuscitation and accentuation of mediaevalism. There could be no greater national catastrophe than a realapse.

The psychologist is destined to play an important part here. He must take up social problems in the concrete setting in which they occur and apply tools which modern scientific technique has placed at our disposal and which have already proved useful in several fields. Following the field-theoretical method he may see that behaviour occurs in a social field which is a topological rather than a metericised field. It is a continuum of many dimensions. An individuals social behaviour is characterised by his membership-character within a field region and the degree of his social locomotion would depend on the number and character of barriers in that region. The bership-character within a field region and the degree of his social locomotion between its division because the whole structure is taken as a static and rigid body. On the other hand social psychology must employ concepts which emphasise dynamic behavioral fields where an individual's responses are seen to flow from a totality of factors (conscious and unconscious) operating in different ways.

A student of social affairs must attempt to investigate these factors and assess their influence and try to gain an insight into their operation. In this way he will acquire a sympathetic understanding of individuals or groups and their distinctive behaviour-patterns. Our need today (as much as the need of the world) is to develop this understanding of the operation of my neighbour's mind. And, in stead of looking upon the process of his thinking and reasoning as warped and inevitably mistaken we may pause to analyse and understand the deep-lying mechanisms of his motivation and the complex social-biological influences which give direction and relevance to them. These mechanisms and influences, these vectors of his mind, have to be investigated and given other directions and different orientations. And, since tensions and conflict rise in the mind and are often due to impatience or lack of social understanding, they must be studied and analysed and attempt should be made to recondition the individual or the group affected to healthier or more approved modes of action. This process of re-education and changing settled reaction patterns is the great task before psychologists educationists and reformers alike. But the main responsibility rests with the students of human mind and behaviour.

The psychologist must take advantage of the democratic process which is coming more and more to be recognised as a way of life which offers maximum opportunities for an individual's development. It is true that we have not yet attained a satisfactory understanding of this process in our country, but we must help educate men and orient them to it and build in reactions which would develop it. Strictly, the educator and the psychologist have to be one and they both must bend their energies to the great psychologists, educationists and reformers alike. But the main responsibility is task of changing attitudes and training us for democracy. But the social psychologist must not aim at a dead homogeneity where individual differences are utterly levelled down and patterns of behaviour are thoroughly regimented. The psychologist on the other hand, aims at what has been called 'orchestrated heterogeneity' where individuals make their distinctive contribution and at the same time heighten the tone of the whole society.

In summing up I may be permitted to conclude by making a few suggestions:

(1) The present world order with its tensions and conflicts makes research in the individual's mind and his reactions imperative. If the present civilisation which embodies elements of undoubted excellence has to be saved, a great deal of emphasis must be laid on social sciences and the development of scientific psychology which is basic to them.

(2) For this a field-theoretical approach in psychology seems to be an appropriate view-point which must guide and organise psychological research in systematic psychology as well as in applied fields.

(3) The two fields which demand immediate study are educational and social phenomena. Mental testing has to be strengthened by systematic research in experimental psychology, and before standardised tests of general intelligence are made ready, work on achievements tests may be emphasised as fairly valuable supplementary information about an individual's mental status. In social psychology work must begin by field surveys of families and groups for understanding deep-lying motivation of age-old habits, beliefs and customary behavior such as caste-consciousness and caste-behavior.

(4) For this purpose a Council of Psychological Research may be constituted which will meet at least once a year to review research-work done by various workers in the field, to offer facilities to them and to coordinate their activities. It will publish a report giving details of the main lines of research carried on by psychologists at various centres. In addition it may undertake some other task such as to (*a*) prepare a dictionary of psychological terms in the national language, (*b*) maintain a list of workers, (*c*) publish research monographs, (*d*) encourage research in the design of apparatus and instruments, (*e*) and to develop contact with psychologists in other countries, try to invite experts and organise special courses and lectures by visiting and exchange professors from abroad and in the country.

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SECTION OF ENGINEERING AND METALLURGY

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Presidential Address

THE ROLE OF SCIENCE ON INDIAN RAILWAYS

I acknowledge with great appreciation the unique honour which you have so kindly conferred upon me by electing me as President of this Section. On going through the list of distinguished men who have held this office before, I find that I am the first railwayman who has been so honoured. This is really a cause of sincere pride to me and to the railway administration to which I belong.

I have been intimately associated with the scientific organisation of Indian Railways for over two decades and as such I am fairly well acquainted with this Industry, and this is the main reason for my selecting this subject of "The Role of Science on Indian Railways" for my Address.

As someone has aptly remarked, the history of civilization is in fact the story of transport. Probably the earliest means of transport was the animal on which men sat and carried their possessions. It is true that Transportation is synonymous with Civilization and it is not possible to make any great improvement in the health and education in the villages of India until they are within easy reach for which organised transport is the surest means of approach. We so often use the word path or road to civilization and our national emblem 'Wheel or Chakra' in a way truly signifies this national Railroad industry.

The total track mileage of Indian Railways before the partition was 40,945 miles consisting of 20,952 miles of B.G., 16,109 miles of M.G. and 3,884 miles of Narrow Gauge. After the partition the total mileage of Indian Railways at present is about 34,000 miles as compared with 7,000 miles of Pakistan Railways (E.B. and N.W. Rlys.)

So far as Indian Railways are concerned, the above mileage works out to be one track mile for every 38.5 sq. miles of area of this country, whereas Europe with an equal area has five times the track mileage of Indian Railways.

U.S.A. with a population, one third that of India, has a total track mileage of 250,000 miles which is more than six times that of Indian Railways. Great Britain with a population of one tenth that of India has a track mileage of 50,000 miles.

In India there is a considerable gap between actual demand for transport and the capacity of Railways to meet it adequately. The problem of bridging up this gap is one of acquiring more power, more Rolling Stock and increased Line Capacity.

During 1947-48 Indian Railways had about one million employees on their roll, the total cost of which amounted to Rs. 50 Crores or roughly speaking Rs. 14 lakhs per day but the above figure has increased by atleast Rs. 20 Crores due to the implementation of Pay Commission's recommendations.

As compared with this expenditure, the American Railways annual wage bill for the year 1929 was of the order of 2500 million dollars which roughly amounts to Rupees Two Crores and Eighty Lakhs per day.

Indian Railways spend over Rupees 40 Crores every year on the purchase of stores which range from a pin to a boiler & these consist of thousands of items. It would be interesting to note that the British Railways Stores Purchase Bill amounted to 53 million £. (Rupees 80 Ctores) last year and so far as American Railways are concerned they spend over Rs. 500 Crores every year. In every part of the world Railways are the largest buyers and users of material and in this respect Indian Railways are no exception. I give below a short description of some of the important material used by the Indian Railways.

COAL USED ON INDIAN RAILWAYS

The coal requirements of Indian Railways is about 1/3rd of the total coal-raising capacity of India. The railway requirements are generally of the order of 8½ to 10 million Tons a year. The total probable world reserves of coal of all grades within 6000 ft. of the surface are estimated to be nearly 74 Million Million metric tons or approximately 16,000 times the world's present total annual consumption. Out of these estimated total reserves 51.8% are located in U.S.A., 16.4% in Canada, 13.5% in China, 5.7% in Germany, 3.1% in Russia, 2.6% in Great Britain, 2.2% in Australia and 1.1% in India. According to the latest geological survey report of India the total reserve of Gondawana coal of all grades upto 1 ft. thickness and depth of about 2000 ft. comes to 60 thousand million long tons. As mining is not practicable with seams narrower than 4 ft., the workable total reserve is reduced to 20 thousand million tons of coal having not more than 25% Ash. The coal consumption in India per capita is calculated to be .07 tons as compared with 6 tons in U.S.A. The U. S. A. today produces over 800 million tons of coal per year, out of which the Railroads uses as much as 150 million tons for their requirements. If the loaded wagons of coal for use on American Railroads for a year are kept standing on a track they would have a length of 24000 miles or a distance equivalent to the circumference of the earth. In India, Railway Industry uses the largest quantity of coal, which is approximately 8½ million tons a year. In a modern steam locomotive, 70 to 80 Lbs. of Bituminous Coal is used per sq. ft. of grate area per hour. Taking the grate area of 50 sq. ft. for our B.G. locomotives it would amount to roughly 3750 lbs. of coal per hour per locomotive. According to the experiments done in U.S.A., about 1/5th of the locomotive fuel is used at periods when the locomotive is not doing any useful work, i.e., in firing up, waiting for trains, standing on sidings and passing tracks, delays at terminals and waiting at ash pits. Although all this appears to be a waste but it cannot be considered as such, as the locomotive must spend sometime in yards, terminals and sidings. All these are essential activities incidental to operation, but these periods must be reduced to a minimum as far as possible. Now the remaining 4/5th of the fuel used by a locomotive is consumed for hauling trains. It would be interesting to study the distribution of this fuel when it is actually employed for operation. It has been estimated by experiments done in U.S.A., that 70% of coal used is applied for making steam, the remaining 30% being used as follows:—

14% goes out of stack as hot gases. This can be easily verified from the fact that 1 ton of coal requires approximately 12 tons of air and this air is heated from atmospheric temperature i.e. from 70-80°F to 500-600°F while leaving the stack. 8% goes out of stack as cinders, 4% goes out of stack as unburnt gases, 4% goes out of the firebox in Ash pits.

Now out of 70% of coal which is applied for making steam, 5% is lost by radiation, 6% in air-pumps and blowers, and the remaining 59 % goes to cylinders, and of this 52% passes out as exhaust steam thus leaving only 7% for work at the draw-bar, and even out of this 1% is used up in overcoming the friction.

The above heat distribution ratios, although taken from American experimental results, are equally applicable to Indian Railways. Any effort made in this country to reduce these losses even by 1% would show a saving of 70 thousand tons of coal per year which is equivalent to 20 lakhs of rupees.

It is probably not easy to appreciate the significance of the amount of coal used by Indian Railways. The total annual coal requirements of Indian Railways is such that loaded wagons when kept on the track will cover a distance of 3500 miles. The coal requirements of Indian Railways for the month of August 1949 are given below:—

Class I Railways:		
E.P.Rly.	51	thousand tons
Assam Rly.	7	,, ,,
G.I.P. Rly.	152	,, ,,
E.I. Rly.	250	,, ,,
B.B & C. I. Rly.	94	,, ,,
O.T.. Rly.	56	,, ,,
M.S.M. Rly.	73	,, ,,
S.I. Rly.	36	,, ,,
B.N. Rly.	129	,, ,,
Jodhpur Rly.	7	,, ,,
Bikaner Rly.	5	,, ,,
Nizam's State Rly.	17	,, ,,
Mysore Rly.	9	,, ,,
Sorashtra Rly.	12	,, ,,
Class II Railways	4700 tons	
Class III Railways	8300 tons	
Total	910 thousand tons per months	

Taking the cost of coal at a flat rate of Rs. 30/- per ton it amounts to Rupees two Crores Seventy-three thousand per month or approx. Rupees Thirty Crores a year.

Briquetting of Coal Dust:—It is a well known fact that a great amount of coal slack or dust is produced at the collieries as well as in the course of transit, i.e., while loading and unloading. This can be easily verified from the fact that over one million ton of coal slack is lying at the collieries which cannot be used. These coal fines apart from being unsuitable for firing in Locomotives are in fact a source of fire risks. Railways have been trying all sorts of ways and means in India to use up these fines in some suitable manner but apart from making a few briquettes with binders such as coal-tar, pitch, bitumen and cowdung no substantial advancement has been made in this line. Apart from cowdung all other binders are very expensive and represent about 60 per cent of the cost of coal for briquetting it. The use of cowdung is of course prohibitive on account of its national importance as a fertilizer. In my opinion its use for this purpose should be prohibited by law.

Germany and France have long been engaged in briquetting by pressure without the use of a binder. The slack is subjected to a pressure of roughly 1000 atmosphere and the temperature increase obtained as a result of this pressure is sufficient to partly soften the low melting bitumens of the coal which give a binding action to the coal particles. Bituminous coals containing hydrogen over 5 per cent are strongly caking and therefore lend themselves easily to briquetting with this process. The Tilamenstone briquetting plant near Dover is capable of manufacturing 20 tons of coal briquettes per hour and most of these briquettes are used for Locomotive firing

Price Structure of Coal :—All seams in the collieries situated in Bihar and Bengal are graded by the Coal Commissioner's Department from analysis of samples taken at the mine. Each grade has a pitmouth price fixed by the Government. The collieries do not check the quality of coal wagons despatched although the equipment required for the work is neither expensive nor difficult to obtain. It is therefore very necessary that the consumers must have the coal tested on receipt. By referring to the existing rates of coal we find that the decrease in price per ton of coal from Grade I to Grade II and from Grade II to Grade III A and III B for the Jharia seams is only taken at six annas per ton. From this it is apparent that the price per ton of coal is not commensurate with its quality on the basis of fuel value since the price difference between the various grades is too small. In other words the best grade coals have been devaluated and inferior grades have been over-valuated with the result that the suppliers have no incentive to supply better grades as they do not stand to gain financially by supplying superior grade of coal. Moreover, it is probably due to this low margin of difference between the prices of various grades that almost all the consumers ask for best grades although it may not be actually necessary for their use.

By referring to specifications of other countries we find that the price per ton of coal is reduced by 2% for every rise of 1% in the Ash Content of Coal. This would mean that the coal with 50% Ash would have zero or no value. The coals of India unfortunately are difficult to clean, whether by hand picking or by washing as the foreign matter is very finely dispersed throughout the body of the coal.

The price in Rupees per ton of coal is generally governed by commercial, political, international or other considerations and to avoid these issues we should choose a scientific scale of price point varying from 0—100. For a Coal of zero ash and zero moisture the price is taken as 100 point per ton. In European countries a coal with 50% Ash is given zero value but in India where the ash contents are generally of the higher order and are difficult to clean, a coal with 66.6% Ash would be considered useless and given zero value. The formula for price point may be given as follows: –

$P = 100 - M - 1.5A$ where P is the price point, M is moisture per cent and A is the Ash per cent.

The practical applicability of the above formula to the existing grades would be of interest. It is necessary to fix the value of 100 price point and its present value may be taken as Rs. 30/-. The theoretical coal with zero Ash and zero Moisture would be valued at Rs. 30 per ton.

If a coal sample for example has 16% ash and 2% moisture its price point would be:—

$P = 100 - M - 1.5A = 100 - 2 - 24 = 74$. And the price of a ton of this coal would therefore be:—

$\frac{74 \times 30}{100}$, that is equal to Rs. 22.2.

According to this the following price structure for various grades of coal has been calculated.

TABLE II

SUGGESTED PRICE STRUCTURE OF VARIOUS GRADES OF COAL

Grade	Ash+Moisture percent	Price (100-M-1.5A) Rs.
Selected A	14+2	23.1
" B	16+2	22.2
Grade I	20+1	20.7
Grade II	24+1	18.9
Grade IIIA	28+1	17.1
Grade IIIB	34+1	14.4

Indian Railways always insist upon getting coals to standard grades but in large number of cases it has been noticed that when check analysis are carried out the consignment are generally of much poorer quality. It may be pointed out here that in cases of coals having 33% Ash, every third wagon of this coal would be engaged in carrying useless material thus locking up a large wagon capacity of the country. In the interest of economy of transport as well as for the efficient utilization of fuel in the locomotive, it is suggested that a very deterrent action in the form of penalty should be introduced in the specifications so that the Colliery Owners may be forced to have their coal supplies tested and analysed before despatch to the consumers. In the past for want of suitable testing equipment at the collieries they have not been able to ascertain the quality of the coal with the result that the useless insert matter is not only carried by the railway wagons but the railway operations suffer considerably on this account. It is very essential that Indian Railways should have proper coal testing centres where quick and ready methods of testing should be applied for checking the quality of the coals before acceptance.

BOILER WATERS FOR LOCOMOTIVES

An average locomotive using an average quality of coal, evaporates about 1 gallon of water per sq. ft. of the heating surface area. In the case of water having a hardness of 14°, it will produce 2 lbs. of scale per 1000 gallons of water evaporated. This scale in a boiler acts as an insulator and therefore a considerably large number of heat units have to be used to get the necessary steam pressure in the boiler. In some cases due to overheating this results in bursting or bulging of boiler tubes. In addition to this heat loss which is incurred due to the deposition of scale, the other troubles generally encountered are those of corrosion, priming and caustic embrittlement. To inhibit corrosion in the boiler the water is generally reconditioned to give certain amount of free alkalinity. As regards priming, some authorities maintain that it is caused by the concentration of sodium salts in the boiler, whereas others are of the opinion that it is due to the small particles of solid matter left in suspension. The above three main troubles i.e. scaling, corrosion and priming are generally met with in all boiler waters and therefore Locomotive Engineers always resort to have their boiler feed waters suitably softened and treated before using them for boiler purposes.

While water softening has made much progress in foreign countries, as will be seen from the facts which are reproduced further in this paper, it is only in its infancy in India. Even Railways that consume large quantities of water per day have only recently begun to appreciate the immense possibilities of savings in running costs with a properly softened water. B.B. & C.I. Rly. was the first Railway in India to start water softening and their plant at Abu Road was installed as early as 1911. The success of this softener, which showed a saving of Rs. 38,000 per year led to the adoption of water softening schemes on a number of their stations. Since then, other Railways in India also began to appreciate the importance of softened water and several plants were started on different Railways. The enclosed table shows the location of water softening plants on Indian Railways in operation along with type and capacity of the plant in each case. If will be observed that no railway has got any systematic installation of water softening plants whereby their engines could run entirely on softened waters. The result has been that a mixture of untreated and softened water is being used all over. Even under these unfavourable conditions the experience of every railway has been encouraging due to savings in running and repair costs, and attempts are now being made to multiply softening plants on many railways so that maximum benefit could be derived by running engines entirely on softened water. It is surprising to note that in a vast country like India with an extensive steam locomotive traffic, there are not more than 70 softening and treatment plants in operation on all the Indian Railways. The total water consumption for locomotive use on Indian Railways comes to about 12 thousand million gallons per year whereas the total softened quantity is only about one thousand million gallons.

In 1944 Inglis-Appleton Mission drew the attention of the Indian Railways to some of the benefits to be derived from the softening of Locomotive Feed Waters and made the following comments on this subject:—

> ''Generally speaking the water supply for Locomotives throughout the country is of poor quality and entails very frequent washing out of boilers. The distance runs between washouts varies from 500 to 800 miles, few engines are able to go beyond those figures.
>
> We understand the question of water softening has been given much consideration but so far as we can learn it has only been carried to a conclusion on two Railways. The experience on those Railways has been so favourable that they propose to instal many more softening plants. Before water softening was introduced, all engines required washout every 500 to 800 miles on an average but after plants had been in operation engines now run distances of from 3,600 to 8,000 miles, a vast improvement. As an ordinary washout occupies a period of 8 to 9 hours, the saving in time, labour and the increased availability of the locomotive must be evident.
>
> It is strongly recommended that water treatment should be further investigated and pressed to a definite conclusion in order to obviate the necessity for such frequent boiler washings with the consequent removals of engines effected from the availability list. Under the stress of heavy traffic demands this is a serious handicap apart altogether from the cost, which on a year's working must be very large and the saving which would accrue would pay for many softening plants."

Water Softening Plants and Wayside Treatment Systems in Operation on Indian Railways

WATER SOFTENING PLANTS AND WAYSIDE TREATMENT SYSTEM IN OPERATION ON INDIAN RAILWAYS

B.B. & C.I. RLY.			JODHPUR RLY.			JAMNAGAR (*Contd*).			B.N. (*Contd*).		
STATION	Type	Capacity	STATION			STATION	Type	Capacity	STATION	Type	Capacity
PALGHAR	L.S.	6.0	GIDHRA ROAD	LS.		SASANGIR	L.S.	4.0	HOWRAH	L.S.	6.0
DHANU ROAD	,,	,,	BARMER	,,		VISAVADAR	,,	4.0	MACHABA	B.E.	4.0
SURAT	,,	,,	BALOTRA	,,		G.I.P. RLY.			BAURIA	,,	4.0
BROACH	,,	,,	MARWAR PALI	,,		POONA	W.T.		BALASORE	W.T.	
BARODA (Yard)	,,	10.0	MARWAR JN.	,,		URULI	L.S.	6.0	JENAPUR	,,	
BARODA (Station)	,,	6.0	MERTA ROAD	,,		DHOND	,,	6.0	CUTTACK	,,	
ANAND	,,	6.0	NAGAUR	,,		POMALVADI	B.E.		KURDA ROAD	,,	
NADIAD	,,	6.0	BIKANER RLY.			BHALAVNI	L.S.	6.0	KALAPUR GT.	,,	
KANKARIA	,,	6.0	BIKANER	L.S.	4.0	KURDWADI	,,	6.0	RANBHA	,,	
VIRAMGAM	,,	6.0	HANUMANGARH	,,	4.0	MAHOL	,,	6.0	CHATRAPUR	,,	
GODHRA	,,	6.0	MAHAJAN	,,	4.0	M.S.M. RLY.			GANJAM	,,	
SEVALIA	,,	6.0	DHIRERA	,,	4.0	GADAG	L.S.	4.0	PALASA	,,	
SURENDRANAGAR	,,	6.0	SURPURA	,,	4.0	BOWRINGPET	L.S.	4.0	KOTABOMMALI	,,	
PALANPUR	,,	1.4	CHURU	WT		RAJAHMUNDARY	,,	4.0	DUSI	,,	
ABU ROAD	,,	3.5	JAMNAGAR RLY.			WALTAIR	,,	6.0	SANTRAGACHI	B.E.	4.0
MORI BERA	,,	1.4	VEREVAL	LS.	4.0	B.N. RLY.					
NEEMUCH	,,	1.4	SHAPUR	,,	4.0	VIZIANAGRAM	L.S.	6.0			
MHOW	,,	2.8	JUNAGADH	,,	1.4	BHOJODIH	,,	6.0			
BANDIKUI	,,	1.4	PARACHI	,,	4.0	BHADRAK	,,	6.0			
MEHSANA	,,	2.8	DELVAIA	,,	4.0	SHALIMAR	,,	6.0			

NOTE

L.S.=Lime soda Type Plants.
B.E.=Base Exchange
W.T.=Wayside Treatment

Capacities of Plants given in Thousand Thousands of Gallons per hour.

As a result of this recommendation, the Railway Board appointed an expert committee consisting of Mr. J. S. Hancock of L.M. & S. Railway and the Author to investigate and report on the subject of water softening on Indian Railways. The report of this Committee was submitted to the Railway Board in June 1945, and has since been receiving the active consideration of the Railway Board.

WATER SOFTENING IN FOREIGN COUNTRIES

U.S.A. :—In U.S.A. water treatment has made a remarkable record of savings during war years. In 1944, according to the 33rd Annual Report of the Director of the Bureau of Locomotive Inspection, extensions were granted to the time of removal of flues to 1302 locomotives. This alone is sufficiently indicative of the effect of water treatment, for no such extensions could have been granted if the flues had not been clean.

According to the report of Mr. C. R. Knowles, Superintendent Water Service of the Illionois Central System, published in the Railway Age of 1943, the Life of Flues and Tubes in the 60 locomotives under observation was increased from 5 to 15 years. The life of fire boxes was doubled i.e. from 10 to 20 years. The combined savings each year in the cost of flue tubes and fire box sheets was enormous, in addition to savings in critical material and skilled labour that was effected through water treatment programme. According to the latest figures, locomotives in U.S.A. consume about 437,000 million gallons of water each year. It is estimated that 44% of this water is being treated in full or in part, thus removing or making harmless more than 220 million lbs. of scale annually, saving about 30 million dollars per year. The same source states that the treatment is being used at 5000 watering stations and that there are still 8250 additional stations at which water treatment was expected to be installed before long.

According to the Report of Master Boiler Makers' Association U.S.A., it is a matter of simple calculations to prove that if the work produced per month per locomotive during World War II had been the same as in the first World War, U.S.A. should have needed 80,000 locomotives, an increase of some 40,000 units over their actual inventory. Had it been necessary to provide this additional power it would have cost U.S.A. several Billion Dollars, taking several years time to build, and the manpower that would have been used for making these locomotives could not have been used to make battleships, tanks, air-craft and all the other tools of modern warfare.

U.K. :—In 1930, the Locomotive Water & Fuel Committee of L.M. & S.Rly. while investigating the effect of hard feed water on locomotive boiler maintenance found that during the year 1927-28 workshop repair costs for the 45 compound engine boilers stationed in Scotland were lower by 62 £. per engine per annum as compared with engines stationed in Midland Division in England. The Committee also found that the Running Shed maintenance cost of these boilers showed a difference of 35 £. per engine per annum in favour of Scotland. From experimental evidence it was concluded that the Fuel Consumption of the Scottish Engines was 2½% less than the English engines. These differences were found to be due to the Locomotive Feed Water supplies in Scotland being Soft, whereas feed waters in England were generally hard and often corrosive.

As a result of this investigation it was decided by L.M.S. Rly. to erect 28 water softening plants in England on the Euston-Carlisle and St. Pancras-Carlisle main lines. The first plant was brought into service in May 1932 and 27 plants were in operation by January 1933. In consequence of the improvement in boiler conditions which was being noticed by the introduction of these plants, 22 new water softening plants in the Derby-Bristol, Crewe-Holyhead and Yorkshire-Lancashire were installed in May 1933. By the end of 1944, they had completed 175 plants which had cost them about 800,000 £. This will give them approximately 90% of treated water. This Railway has only one type of plant i.e. Lime-Soda, but they are experimenting with Base Exchange Plants at some of their stations.

The following points may be summarised from the experience of water softening plants on L.M.S. Rly.

(1) Ratio of softened to unsoftened water governs savings and that maximum benefit can only result from the use of 100% softened water, even a small percentage of crude water causing a serious decline.

(2) Water with less than 10° of Hardness should be treated with Soda-Ash and Tannin but waters with 10° or more of hardness should be properly softened.

(3) All the waters whether softened or treated must contain excess soda-alkalinity. This will prevent corrosion of steel but to avoid corrosion of copper, tannin must be added.

(4) All water softening plants should be of the same type i.e. either Base Exchange or Lime Soda and not mixed. They should be simple to operate and easy to control.

South America:—In 1944 South American Railways had 300 Base Exchange Plants in operation extending over nine railways. These plants soften approximately 12½ million gallons of water per day, each plant being capable of treating 42,000 gallons of water per day. The approximate cost of each of these plants is about 1000 £.

As regards Priming, South American Railways have reached the concentration of 5320 g.p.g. without any signs of priming but they generally maintain an average figure of 730 g.p.g. by blowing down.

Taking the case of one Railway alone i.e. British American Pacific, the savings obtained during one year ending June 1939 as given by the Chief Mechanical Engineer of that Railway comes to 23591 £. against a capital cost of 25000 £. The general comments of the Chief Mechanical Engineer are worth quoting, "Softened Water Service continues to prove its value, boilers remain clean, difficulties due to priming are almost unknown and corrosion is being steadily eliminated. The Railway Chemical Engineers' Report sums up the situation in these words: "In general it can be stated that the softened water service has again given a good account of itself and by enabling boilers to be kept clean has assisted by materially obtaining the maximum energy from inferior fuels that have to be used."

GREATER AVAILABILITY OF LOCOMOTIVES AS A RESULT OF SOFTENING

The greater availability of steam locomotives, by using softened water cannot be easily evalued in terms of cash.

In addition to the savings in boiler repair costs which can be easily ascertained, there is the additional availability as a direct result of the time saved that would normally be spent in these repairs.

Though figures of increased fuel economy due to the greater heat transfer in a cleaner, and scale free heating surface of the boiler is shown sometimes at 2 to 4%, the actual economy is difficult to determine. What is certain and easily computed is the number of engine hours that are wasted in washing out.

Very few plant manufacturers, chemical engineers, or others have illustrated in figures, the actual availability of steam locomotives that can be achieved by softening the feed water. In this respect the Author has carried out very exhaustive investigations with a view to collect data extending over a period of years. On the B.B. & C.I. Railway's Metre Gauge System in particular, all five districts have been dealt with in detail.

For instance, taking a particular shed like Abu Road having a total number of 47 engines, the total number of washouts absolutely essential comes to 5640 per annum, i.e. one washout per engine every three days. Under the proposed economy scheme of the author each engine should be given a washout every 15 days thereby saving the time occupied by 8 washouts, equivalent to a saving of about 80 hours per Loco. There are 94 engines in the Abu District which require 11,280 washouts per year, occupying a total of 1,12,800 hours. The number of hours saved by the reduced washout programme would be 90,240. If all these hours could be utilized it would be the equivalent of 10 engines working continuously for 24 hours a day throughout the year. Likewise, all other districts have been dealt with by the author in detail and a grand total of 509,040 hours saved which is theoretically equivalent to 56 engines working continuously for 24 hours a day throughout the year.

Everyone realises that it is not possible to utilize all these hours, but each Mechanical Engineer should be able to visualize the economy that can be effected in locomotive working on account of this extra-availability and the resulting savings in labour and time. In certain cases a readjustment in a link and keeping particular locomotives in longer continued service will reduce the number required, or the transfer of the extra power to another link or section to relieve the pressure would result in improved efficiency.

Good proof of increased availability is evident from the actual experience of some South American Railways. Incidentally, softening has been practised on those railways to a far greater extent than any other country in the world, and it is extremely necessary for a country like India which is very short of Locomotive power at present to make as intensive a use of our existing stock of Locomotives as possible by providing properly softened and conditioned water for their use.

USE OF METALS ON RAILWAYS

The next important material used on the Railwaysis that of Metals, which during the year 1943 amounted to a sum of Rs. 26 million. Permanent Way materials, *i.e.*, rails, fishplates and metal sleepers amounted to seven million rupees. If we look to the railway system as a whole, we can easily see for ourselves what a large amount or metal is involved in the construction of locomotives and other rolling stock and on the track on which they run. These rails of course wear out due to constant use and corrosion and have to be replaced say after every 35 years.

The total quantity of steel used in the railway track on Indian Railways approximately amounts to 50 lakhs tons. In U.S.A. a replacement figure of 4 to 5% or 8 to 10 tons of steel rails per mile of track per annum has been arrived at as a result of extensive experiments. According to this estimate, the steel required for annual replacement of our railway track in India would come to approximately 2½ lakhs tons. This is evidently a high figure and our steel producing capacity in this country cannot meet this demand. In the case of some European countries only 2% replacement figure is computed for this purpose and even according to this figure Indian railways would still require one lakh tons of steel for rail replacement every year. It would be of interest to note that Railroads in U.S.A. consume 2 million tons of Steel every year for replacement of their railway track.

According to the figures that have been collected from some of the continental railways, I find that as a result of heat treatment 43 million tons of traffic caused a wear of one sq. centimeter in cross section as compared with 14 million tons for the same amount of wear before treatment. I recommend that special Medium Manganese steel should be used extensively.

We have over 85 million sleepers in the railway track in this country and taking an average accepted replacement figure of 4%, we would require over 3 million sleepers a year. In U.S.A. they use a replacement figure of 6.5%, and replace 50 million sleepers every year in a track having 750 million sleepers. In the case of wooden sleeper Indian Railways should have a proper creosoting plant to extend their life.

Railways spend a very large sum of money in the upkeep of the Permanent Way. It has been stated that 60 per cent of the total cost spent on Permanent Way is due to the joint maintenance and the rest in its upkeep. This maintenance cost could be considerably reduced by welding of rails. The use of these welded rails on main lines, sidings, tunnels and underground lines has extensively increased throughout the world particularly in U.S.A. One of the most important uses to which welding could be applied is in the reconditioning of the crossings. It is estimated that by this means the life of a crossing is extended by 50 to 70 per cent at less than 25 per cent of the cost of new crossings. According to the Wedgewood Enquiry Committee's Report, short length rails varying from 21 to 24 ft. which are generally regarded as scrap were welded on to 69 and 72 ft. lengths and safely used in South Africa. This subject involving the reduction in the number of rail joints is a very important subject of research on Indian Railways and has been very strongly emphasized by the Wedgewood Commission.

According to the calculations of the American Engineering Association, the prevention of a rail from expending or contracting causes an internal stress of 195℔s. per sq. inch for each 1°F change in temperature. Thus a change in temperature of 100°F would create an internal stress in the rail of 19, 500℔. or 8.75 Tons per sq. inch.

To minimise these high internal stresses, it is customary to lay long rails at the mean average annual temperature, and thus reduce the tendency of the rail to buckle, if the fastenings should become weakened. One of the great difficulties with long rails, apart from the practical limitations provided by transport, is that opening up of the track can be done only at a opproximately the same temperature as that at which the rail was laid. This places severe limitations on a maintenance programme and can become even more serious in the event of a rail fracture when it is necessary to remove the defective section. It is for this reason, undoubtedly, that use of very long welded rails has not spread more rapidly.

The longest stretch of continuous welded rails in U.S.A. at present is 12782 ft. There are in U.S.A at least ten stretches of continuous rails each more than a mile in length. Previously Thermit process was extensively used for welding but it has been replaced at present by Flash-butt welding process which is giving very satisfactory joints.

It cannot be claimed for a Welded rail joint, no mater by what process it has been formed, that it has all the characteristics similar to or as good as virgin rails. This is almost self-evident when one considers the rough heat treatment which the adjacent metal must undergo during the welding operations. It is of interest to note in this connection that when a welded joint is tested to destruction, either by slow bending or by a "Tup" test, fracture does not usually occur in the plane of the weld but in a plane in one or other of the parent rails close to the weld where the drastic heating and cooling has had the most serious effect on the structure of the steel.

The smoother riding qualities of the track, with welded joints, provide greater comfort to the travelling public. This is only one advantage which may be claimed for it, and which is of general interest. There are many others of a technical-cum-economic nature, which are enumerated below :—

(i) With the ordinary fish plated joints, the rail develope "end batter" and tend to "hog". This shortens the useful life of a rail. In a welded rail, this is absent.

(ii) When a locomotive passes over a bridge , with rail joints over girders, the "rail joint effect" as it is termed, causes an increased loading on the bridge, which consequently has to be much stronger and this requires the use of more steel. The absence of rail joints over a bridge girder, therefore means a saving in steel.

(iii) On Sections of the line which are electrified both for traction and signalling, track Bonding" is necessary at joints. This is not only eliminated where the joints are welded but the continuous welded rail is also better.

METALS IN WORKSHOPS

Now coming to the workshops where all rolling stock is manufactured and repaired, we notice that every process involves the use of metals in some form or the other. Some parts are cast in the Foundries with which practically every workshop is equipped though very few of them are designed on modern lines and operated scientifically.

Indian Railways are the largest users of Pig Iron for their foundries and they use about 1.9 lakh tons every years. In terms of outturn it comes to about one lakh tons of finished castings.

As a result of research conducted at Ajmer from the funds provided by the Railway Board, it was possible during the war to produce High Duty Cast Iron comparable in physical properties to that of Meehanite—a patented alloy. However, a great deal needs to be done to standardize all the conditions which will enable us to produce our castings of uniform and standard quality. Some of the railways will not be able to avail of this research unless their furnaces are remodelled on proper scientific lines.

As regards non-ferrous foundries, we find that the melting technique in most of the Railways is far from being modern. From the information collected recently I find that Indian Railways use Non-Ferrous metals worth over Rs. 85 Lakhs every year. I think Indian Railways are the largest buyers and dealers of non-ferrous metals in this country, but it is surprising to know that no metallurgical research worth mentioning is being done either to improve the quality of these various alloys, or to develope cheaper and new ones. Indian Railways at present have in their custody non-ferrous scrap weighing hundreds of tons and excepting its disposal to merchants, railways are not in a position to recondition this scrap to their own advantage for want of proper scientific equipment for refining etc.

I would strongly advocate that special experimental work must be undertaken to refine the various grades of scrap available for re-use on the Railways.

India is very deficient in all non-ferrous metals and this is particularly so in the case of Tin which is an expensive metal but is considerably used in various alloys which are manufactured for the railway rolling stock. During these days when the conservation of Tin has become a dire necessity, attempts should be made to develop Tin substitutes for Tin bearing alloys in order to relieve presure on the demand for this metal. Several contributions have been made in this direction by the British Non-Ferrous Research Association for manufacturing alloys free from Tin as substitutes for admiralty Gun Metals and other Bronzes. As a result of research work done in this field in U.K. and U.S.A., Tin-free Bronzes which are known by the name of P.M.G. and Everdur Alloys have been developecd successfully. During the war when there was acute shortage of Tin, the problem of making similar Tin-free alloys in this country for use in the Railways was entrusted to the Author and as a result of our investigations we were able to produce Tin-free alloys for the first time in this country. These alloys were tested under various conditions in the Laboratory and were found to give very satisfactory results as compared with Tin Bronzes. Recently as a measure of national economy the Railway Board have again taken up this question and we soon hope to put these alloys in commercial use which would show a very great saving towards the cost of non-ferrous metals.

USE OF LIGHT METALS

The subject of reduction in weight of Rolling Stock was further discussed at the International Railway Congress Association held in Switzerland in 1947, and much useful work has been done in this direction uptil now.

In 1933 it was agreed by the International Railway Congress that great deal of reduction could be made by employing various welding processes for forming assemblies and using light alloys for certain internal fittings not subjected to any appreciable strain. Since then we have witnessed a gradual development in design tending towards a general reduction in dead weight without in any way diminishing the safety or comfort of passengers. The Netherland Railways have reported a saving of 5 tons in the weight of their coaches by employing electric welding in place of rivetting.

The Association sent out detailed questionnaire to 42 Railway Administrations of the world, out of which only 27 replied.

In every country it is the practice to compare the weights of vehicles by taking an essential basis the weight per seat or per passenger capable of being carried. The dead weight varies according to the type of vehicles. By using light metal streamlined body, it was experimented in France that the total weight reduction per seat achieved in comparison with all steel stock which was 970 lbs., the light weight metal used gave the dead weight per seat of 606 lbs., showing a saving of 37.5%.

The French National Railways consider that unless we use special steel or light-alloys in constructing the principal parts of the underframe and the body, it is not possible to bring down the dead weight below 30 tons. The Swiss Federal Railways fix the limiting figure of 25 tons for their light weight steel coaches.

It seems clear from the above that the French coaches and the light weight Swiss vehicles represent the lightest type of stock that can be considered practicable in the existing state of technical development without incurring any diminuation in the standards of comfort and safety.

The Michilin Company have recommended the use of pneumatic tyres for vehicles with a dead weight of 16-18 tons capable of being constructed in stainless steel or ordinary steel and light alloys. The use of pneumatic tyres puts the question of comfort and the stresses effecting the under frame and body under an entirely different angle from that involved with vehicles on two hard surfaces in contact. This is a very suitable field of investigaiton in which future designs will tend to develop in their endeavour to obtain further saving in weight.

There are number of pneumatic tyred rail coaches in use on the continent. The latest is a 400 H.P. composite train mounted on pneumatic tyres running on standard guage line. The maximum speed of the train is 80 miles per hour and it weighs 19 short tons and carries 136 passengers. As in ordinary Motor Car tyres, the pneumatic rail tyre is filled with air, the pressure used being 114—130 lbs. per sq. inch.

Regarding the effect of weight reduction on cost of haulage, the Italian State Rlys. admit that these costs fall by an amount equal to a percentage of weight reduction achieved multiplied by a coefficient varying between 0.25 and 0.35, the first figure relating to steam, the second to electric trains. The French National Railways consider that for a 15-coach train of 32-34 tons tare per coach, the average reduction in dead weight of 180 tons or 35% will cut running cost by 10% *i.e.*, by about a third of the percentage of weight reduction.

Weight reduction also offers certain definite advantages not easily expressed in figures :—

(1) the appreciable saving of material for building the vehicle,

(2) reduction in track maintenance weight cost as a result of smaller axle loads,

(3) The possibility of using less powerful and lighter engines thereby causing less wear and tear on the Permanent Way.

In this respect it is interesting to note that Indian Railways have recently designed a new coach which weighs only 65% of the prewar times. The new coach is 70ft. long and 11ft. 8 in. wide as compared with 68ft. and 10ft. respectively of the old design. The weight of an average fully loaded train will be 360 tons as against the prewar figure of 550 tons.

LUBRICATING OILS

Indian Railways use about three million gallons of lubricating oils and greases per year costing over Rupees Two Crore and Thirty-two lakhs. Their requirements vary from Spindle Oil to Petroleum Jelley and Hard

Greases. There are more than fifty items of these Lubricating Oils for which different specifications have been laid down. Most of these oils after use are thrown away to waste for want of suitable refining equipment. It was suggested in my address before the Institution of Engineers in 1946 that every railway should endeavour to refine its own used oils as far as possible and in this respect N.W.Rly. took an initiative and erected a plant for their use. This plant was designed to handle about 100 tons of used oil a year which roughly gave a saving of Rs. 29,000. I suggest that similar oil reconditioning plants should be introduced on other Railways as it would be a source, of great saving to them.

I wîll not go into the subject of hot boxes which are sometimes caused by scanty lubrication as it is a very exhaustive subject by itself, but in connection with the type of lubrication I would strongly point out that solidifed oils have many points in favour of their use, such as, less losses through leakages and splashings which happen in the case of mobile liquids. This loss if not duly replenished would cause hot box for lack of lubrication which will not happen in the case of solidified oils.

The latest development in this field is to have oilless bearing in which the oil is kept absorbed in the spongy pores of the bearing metal which is prepared from metal powders which have been compacted and sintered according to the desired porosity. In order to utilise the lubricating properties of graphite, its fine particles can be mixed with copper, tin, lead and other non ferrous ingredients for the manufacture of porous bearings. There are vast possibilities of powder metallurgy on the railways whereby metals of different melting points can be incorporated into one body. Further information on the subject of Powder Metallurgy can be had from the Author's article published in the Journal of Scientific & Industrial Research.

PAINTS AND VARNISHES

To avoid corrosion and to increase the life of the Railway Rolling Stock and other structures, painting of their surfaces is very essential. Indian Railways use all kinds of paints varnishes, enamels etc. for this purpose the total cost of which amounts to over Rs. 80 lakhs per year. Indian Railways should make full use of the various indigenous materials which are readily avialable in this country in preference to foreign imports.

It has been noticed that practically most of the senior supervisory staff of the Paints & Varnish Department of various railways have no scientific background or technical training of any kind. Their work is more or less of a routine nature and they are not capable of understanding the various operations involved in this work. In the interset of efficiency it is highly necessary that the supervisory staff should have some training in the chemical physical and practical aspects of this industry on which such a huge expenditure is incurred every year. I have included the training course in paints and varnish technology under the workshop courses of study which have been described further in my address under the subject of "Scientific Manpower Reserve", but I would suggest that Indian Railways should have an up-to-date paint and varnish laboratory similar to the one on the L.M. & S. Railway. This research laboratory should have a manufacturing centre attached to it, from which all the requirements of Indian Railways would be easily met and the research laboratory would be able to pay for itself in this way. A similar suggestion has also been made by Paints & Varnishes Panel of the Department of Planning & Development of the Government of India and I think it is highly essential that this work should be taken in hand as early as possible as it would lead to both efficiency and economy.

I have recently learnt from the study of scientific research report of British Railways that they have developed a process whereby one complete coach was completed within two days instead of ten days taken by us on Indian railways. It has been well established that the drying property of the paint film is largely dependent upon the quality of the pigments used. In cases where the pigments have high oil absorptive power, the paints made from them will not easily dry unless excess of thinners are added and consequently large number of coats will be required to impart proper opacity to the surface. This is probably the reason why our coaches and wagons on Indian railways have to be given more coats as compared with British practice. The increased production drive of our country demands that outturn of our coaches from the workshops should be as quick and speedy as possible and for this purpose comprehensive scientific research is necessary.

LOCOMOTIVES AND COACHING STOCK

In meeting the ever-expanding modern needs of an efficient system of Railway Transport, Power plays the most important part. It is to be regretted that in designing and planning this system of transport for India no systematic efforts to meet its future needs were given proper consideration. The Indian Railways were importing complete locomotives built in foreign countries as well as the spare parts required for their maintenance. If at the initial stage steps had been taken to put up the locomotive manufacturing industry in this country, India would have by now made tremendous progress in industrial field. The authorised stock of steam locomotives on Indian Railways on 31st March, 1944 was 5285 B.G., 2456 M.G. and 532 N.G. locomotives, for the purchase of which crores of rupees had to be spent outside the country. Only in Jamalpur (E.I.Rly) and Ajmer (BB&CI. Rly.) workshops steps were taken to build Locomotives and Boilers as early as 1919. Upto 1923 Jamalpur workshops manufactured 214 complete locomotives and 103 additional boilers while uptil 1941, BB & CI.Rly. workshops at Ajmer built 444 locomotives complete and 339 additional boilers. This shows that the requisite intelligence and technical experience to run this industry was not lacking in this country.

During the first great war, when the imports were severely restricted, the Govermement of India felt the necessity of making Indian Railways independent of foreign imports and outside sources so far as the supply of materials for locomotive manufacture was concerned.

Since then persistent representations were made by the public to start this industry in this country. In 1918 Government of India issued a communique guaranteeing purchase of 2500 B.G. and 50 M.G. wagons in India annually for a period of 10 years and also 160 locomotives and 160 additional boilers during each of the years 1923 & 1924, and 400 Locomotives and 400 additional boilers every year after that. The Peninsular Locomotive Company with a capital of Rs. 40 Lakhs was started to supply these but went out of business without manufacturing a single locomotive for want of Government protection. In 1931 it was decided by the Railway Board that the Government of India should itself run this industry, but the period from 1931-1940 was wasted in schemes and manipulations and no concrete action was taken by the Government of India. With the increasing cost of foreign locomotives, Railway Board placed Messrs. J. Humphry and K. C. Srinivasan on Special Duty to investigate this problem in detail but the recommendations made by this Committee could not be implemented because of the exigencies of the second World War.

As a result of non-availability of replacement and spare parts during the second World War and the subsequent partition of the country, Railway System had to work under a very heavy strain which has effected its power position very adversely. Moreover, out of about 7000 locomotives, 1470 have reached or are about to reach the condemning age very shortly. These will ultimately be scrapped due to prohibitive maintenance cost. Moreover, multiplicity of the types of locomotives renders the maintenance difficult as the spare parts are not interchangeable.

Intensive efforts are now being made to improve the power position of the railways consistent with the growing needs of the country. To meet immediate needs, orders have been placed abroad for 863 locomotives in addition to 10 B. G. locomotives under construction at B. B. & C. I. Rly. Workshops at Ajmer. Out of these U. S. A. has got an order for 303, Canada 350, U. K. 190 and France 23. These consist of 640 B. G., 203 M. G. and 20 N. G. Out of these a large number has already been received and the remaining are expected soon. At the same time Rs. 14 Crore Chitranjan Project at Mihijam for the complete manufacture and production of locomotives in this country is proceeding rapidly. National interest demands that this country must be self contained in respect of key industries like Locomotive manufacture which is of vital importance during national emergency. It is expected that the first Locomotive will come out of these workshops by the end of 1950.

In this connection it would be interesting to have some idea about the quantity of different metals required for the manufacture of a complete locomotive (say XE type) with boiler and tender :—

	Tons
Cast Steel.	25
Cast Iron.	13
Mild Steel.	77
Class IV Steel.	25
Gun Metal, Phosphor Bronze, Brazing Metal, Copper etc.	2
Copper Rods, Fire-box Plates	3
Copper Rivets.	1
White Metal.	¼

AIR CONDITIONING OF RAILWAY COACHES

Air-conditioning is being rapidly adopted on Indian Railways. There are three main types of plants employed :—

(1) Electro-mechanical as used on GIP & EIR,

(2) Cabinet System as used on two GIP coaches from Bombay to Madras (as an experiment).

(3) Ice-activated System as used on BB & CI.Rly.

In the Diesel Mechanical coaches built for the Nizam State Rly., the air-conditioning system provides the passengers with constantly circulating dust free air at the correct temperature and humidity for personal comforts, the desired temperature being controlled by a series of thermostats. Fresh air is mixed with a proportion of recirculated air and is delivered from the evaporative unit through downwardly discharging ducts in the ceiling of the compartment. The refrigerant used is freon and the equipment is controlled by a panel in one of the two driving compartments. The Cabinet system is in fact an electro-mechanical system which is adopted to suit the unit principle and in this case it is not necessary to provide roof ducts. From the study of the different methods of air-conditioning on different Indian railways it has been estimated that the cabinet system works out to be the cheapest of the three methods, It may be said in passing that in the ice-activated coaches a large quantity of ice is required and unless a special ice plant is erected for this purpose as has been done at Shamgarh on the BB & CI.Rly. it is very difficult to work on this system. While making these calculations for air conditioning of coaches we take into consideration the fact that 25 cu. ft. of fresh air per minute per passenger is provided.

ELECTRIFICATION OF RAILWAYS

At present we have only 236 route miles of Indian railways which has been electrified. The electrification of a further 1500 miles track *i.e.* from Bombay to Ahmedabad and Howrah to Moghalsarai (via Grand Chord) at an estimated cost of Rs. 62 Crores is at present under active consideration of the Government of India. If this scheme is taken up, there will be a saving of 600,000 tons of of coal of which 40% would be of high grade quality.

The electric locomotive has on an average an efficiency of 85% and the overall efficiency of electric traction system using thermal power averages from 14 to 17% which is roughly 3-4 times that of steam traction system. This accounts for the reduced coal consumption which it would be possible to economise by the electrification of the Railways.

At lower Traffic Densities, Steam Traction works out cheaper than electrictraction, the reason being that electric traction has the initial burden of high depreciation and interest charges on the cost of Power Station, Transmission and distributing equipment.

The following are operating expenses of steam locomotive as compared with electric locomotive.

	SteamLocomotive	Electric Locomotive
	(Cost per engine	mile in Rupees)
Repair & Maintenance	0.70	0.4
Lubrication	0.06	.01
Water	0.08	Nil
Total	0.84	0.41

RECENT IMPROVEMENTS IS LOCOMOTIVE OPERATION:

Stream Lining.—From experiments done at Pennsylvania Railroad Research Laboratory it has been estimated that at a speed of 100 miles per hour, with a side wind of 33 miles per hour, streamlining showed a saving of 1200 H.P. as compared to normal train. At 80 miles per hour a saving of 500 H.P. was shown. According to Chrysler Company's experiments, the air resistance represents 40% of the total power needed to drive a car. At 60 miles per hour by using stream lining it is possible to save 33% of the power. The above facts clearly signify that stream lining can be a source of very great saving in the coal consumption of our stream power locomotives.

Surface Hardening:—In addition to nitriding and case-carburising processes for hardening metal surfaces, which are used to resist wear of some of the locomotive parts recent metallurgical advances have shown that by silicon-impregnation of steel, it makes the steel parts resistant to corrosion, heat and wear. By this process the metal is subjected to Silicon Carbide and Chlorine at a temperature of 930 to 1010°C. Ferro-Silicon or mixture of Ferro-Silicon & Silicon-Carbide can also be used. The surface is impregnated with silicon upto 14% in the case which ranges from .005 inch to 0.1 inch depending on the time of exposure. This is the cheapest method of imparting valuable properties to steel and is being widely used on foreign railways.

Condenser Locomotive:—Soviet Russia has produced new and improved types of condenser locomotives which can run a thousand miles without taking water. The condensing installation of this type of Loco. converts the steam discharged by the cylinders into water for reconversion into steam as many as 10 to 13 times.

Roller Bearings:—The roller bearings are not dependent on the maintenance of an oil film and have therefore an extremely low starting resistance. In the case of ordinary bearings it is necessary to have an oil film to avoid frictional resistance while starting and until the oilfilm has built up such resistance may go up to 18 lbs. per ton, which under proper Oil Lubricating conditions approximates to a speed of 60-70 miles per hour. In my opinion Railways should resort to the introduction of roller bearings wherever possible.

SCIENTIFIC ADVICE AND CONTROL ON RAILWAYS

By careful study of the various facts connected with the railway industry it becomes evident that the railway needs in the direction of scientific advice and control are practically unlimited. It is hardly realised by non-railwaymen what a diversity of material are used on the railway and to what rigid tests they must comply before they can be accepted for service. The Railways are the largest buyers and users of all industrial products which range from a pin to a boiler. Indian railways for example buy stores worth several crores of rupees as already mentioned.

In the case of metals, we have pig iron of all types, structural steels, alloy steels, ferro-silicon alloys, ferro-manganese alloys, copper, lead, zinc, tin, antimony, aluminium, phosphorus-copper, fusible metals, antifriction metals and hundreds of other alloys. Some of these alloys are forged and rolled whereas others are cast in the Foundry. The heating, forging and casting operations all require very careful scientific supervision and control and any neglect on the part of the operator may lead to very serious consequences due to the defect in the finished product. Since most of the Locomotive parts are subjected to severe working conditions requiring high degree of resistance to wear, heat, fatigue and corrosion, these parts are heat-treated, quenched and tempered under proper scientific direction since even a slight error in metallurgical control would render the metal useless for the job for which it was intended. All these metals before use are subjected to stringent chemical and mechanical tests and their suitability for the particular purpose is fully ascertained.

In the case of failure of metals which occasionally cause derailment or serious accidents, the Railway scientist is expected not only to submit a report about the causes of failure but to suggest ways and means of improving the quality of the metal to avoid further mishaps occurring. The broken tyres, wheels and axles are common occurrences, the causes of which must be diagnosed very carefully. The investigation of Hot Boxes is another very important problem for the Scientist. He must see that proper types of lubricants having high flash-point and correct viscosity are used along with proper types of antifriction metals, which are examined under the microscope before use.

The Railway Scientist has also to see that proper type of refractory materials are purchased on which a sum of over Rs. ten lakhs are spent every year. Physicists are employed to determine the physical properties of fire-bricks such as expansion, contraction, sintering point, and compressive strength at high temperatures under varying loads.

Coal is another important item on the Railways. Every coal supply that is used in a locomotive should be tested in the Laboratory although it is not being done at present and in case of coals having high ash content, their blending with selected grade coal is suggested.

Practically every first class railway in India is equipped with a laboratory where routine testing of materials is carried out. This department deals with the testing of stores and also helps in other ways by giving technical advice and help connected with various problems that arise from day to day.

STATUS OF SCIENTISTS ON INDIAN RAILWAYS

The history of Indian Railways shows that they were not designed on any economic principle, but were started for strategical reasons. The original administration and management of this department was entrusted to high military officials, who were specially brought out from England to run this industry under military discipline, although they had no technical knowledge of railway problems. (This was probably true of most departments of the Government of India of those days; but it was more so in the case of the railways, as their working was then considered to be more or less of a routine nature.)

Not only the locomotives and the rolling stock, but every other item connected with this industry was then purchased from England. Firms of consulting engineers in London were asked for technical advice and help on every engineering matter; and it was not considered necessary to employ any technical or scientific officers on the railways in this country Although great political changes have taken place in our country since then, and many Europeans have been replaced by Indians in some of the important key positions on the Railway, the system of railway working still continues more or less on the same lines, so far as the employment of officers with high scientific and technical qualifications in the Administration is concerned.

It is not generally realised that the standard materials, which used to be supplied by British Firms in the U.K. are no longer readily available there; and, with the departure of some of the experienced technical men, we have been reduced to a somewhat helpless position. The quality of material at present available in our country is much below the standard quality. In a large number of cases, the materials arenot available at all, and substitutes are required to be developed to carry on the work of the

Railway efficiently. All this would require a very serious effort on the part of a large number of trained Indian Scientists, who would have to be employed on the Railways.

As the Hon'ble Mr. Asaf Ali, the then Minister-in-Charge of Transport, stated in one of his speeches—"We can think of no other branch of Science, barring perhaps Astronomy, Biology and Zoology, which does not come into play in relation to the Railway organization at some stage or another."

According to a recent issue of the American Railroads, describing the career of some of the most successful and highly paid men employed thereon, we find that 85% of them held such posts by virtue of their scientific or technical education and experience. Even in the case of the British Railways, the highest administrative posts are held by experienced scientists. In our country, on the other hand, while we hear and read so much about the importance of scientific and technical training for the development of the country, it is both surprising and disheartening to find that no opportunity or scope of any kind is being offered to highly trained and experienced scientific personnel in this key industry of the country. Indian Railways could absorb hundreds of scientists; and I am sure this key industry of ours will derive enormous benefit by their association with the various branches of Railway activity. Unfortunately at present there is no place for a scientist on our railways. I know of no place in this whole industry, where a person with a scientific degree is employed in preference to others. This is a very unfortunate state of affairs and should not be suffered any longer. This is an age of science and competition. As a highly scientific and commercial concern, the Railways cannot afford to neglect the use of science, if they really mean to achieve the maximum success. Moreover, at present our country is facing a period of serious crisis, when all petty and personal considerations must give way and the interests of the country alone should be given the topmost priority

SCIENTIFIC MAN-POWER RESERVE FOR INDIAN RAILWAYS

The work done in the Scientific Laboratories of the Railways is of a highly specialised nature. It requires a comprehensive knowledge of analytical and industrial Chemistry, Fuel Technology and Metallurgy, besides some general engineering experience. The Scientific training given in our schools and colleges is not sufficiently wide or deep, to enable a Science Graduate, however brilliant, to take up the Railway Laboratory work without very extensive post-graduate practical training. We have further no Technological Institutes, where this applied scientific training could be obtained. Therefore, when a new Science Graduate is employed in the Laboratory, a great deal of time and labour of the senior and experienced staff is required to be spent in giving the new recruit the necessary practical training.

The training process generally takes 1 to 2 years. At the end of the period, the majority of these trainees, who could be usefully employed on Railway work, leave the service, as they can get much higher salaries and better prospects in commercial firms, because of the exhaustive and intensive practical training, which they have received in our Railway Laboratories. I know from personal experience that a very large number of our trained Laboratory Scientists have secured very lucrative jobs all over the country; and the training and experience, which they got in the Railway Workshops and Laboratories, has been lost to the Railways. I would, therefore, suggest that the Indian Railways should have a Laboratory

Training Centre, similar to the Training Centre for the Mechanical Apprentices at Jamalpur, where selected batches of Science Graduates could be trained in all branches of testing and scientific control of both ferrous and non-ferrous materials and the other stores purchased by the Railway. A batch of 50 Science Graduates a year would be sufficient to meet the present requirements of Indian Railways. Later on, with the expansion of the existing Laboratories, the number could be increased to meet the growing needs of the Railway Scientific organisation. Ajmer would probably be the most suitable choice for the location of this training centre, as the Locomotive and Carriage & Wagon Workshops there are fairly well equipped for the purpose. The workshops have a Steel manufacturing plant, which can be utilized for the Steel Foundry training. There are also a number of Water Softening Plants close to Ajmer. The existing Railway Scientific Labora tory and Test House could be expanded to cover this scheme.

Following is the general scientific work in which such graduates would be trained in the course of their first year, they could be given specialised training in any one of the following subjects in their second year:—

(1) Cast Iron & Steel Foundaries.
(2) Non-ferrous Foundaries and Fabrication of other Alloys.
(3) Tool Room and Heat Treatment Shop for Metals.
(4) Water Softening.
(5) Manufacture and Utilisation of Palnts and Varnishes.
(6) Fuel problems pertaining to Workshops and Locomotives.
(7) Welding, Soldering, Brazing, electroplating and white metalling
(8) Oils, Greases & Lubricants; Soaps and disinfectants, and their application and use.
(9) Chemical and bacteriological examination of waters, and testing of food material.
(10) Control and uses of Refractories, including cement, sands, fire-clays, fire-bricks, silica bricks, etc.

All such trainees should ultimately be absorbed in one of the Railway Departments in which they have specialised, and they should rise to occupy the most responsible positions in due course.

Such trainees should be paid Rs. 100/- P.M. for the two years of the training period. There after, they should be employed on a permanent basis, either in the Scientific Department or in the Railway Workshops, depending upon their progress and suitability for the different lines, in which they have specialised. The trainees should be required to given an undertaking to serve the Railway for atleast five years after completing their training.

NATIONAL FOUNDRY TRAINING CENTRE

The recent establishment of the National Foundry College in England for the purpose of imparting practical training in the melting and casting technique of various metals and alloys has been so widely appreciated that hundreds of applicants from all over the world have been refused admission on account of the limited space available for their training. The Indian

Railways had decided last year to send some of their mechanical engineers to the above College for getting this training. In my opinion money spent for such a training on a mechanical engineer would be completely wasted as the curriculum of this College clearly shows that this training is meant for a qualified metallurgist who should be fully conversant with the Chemistry of Metals and non-metals to get full benefit out of this course. However, I suggest that instead of sending people abroad, a similar foundry training school should be started on Indian Railways for the training of foundry workmen and supervisory staff who are at present quite ignorant about modern methods of production.

At present, most of our senior subordinate staff in the workshops, on whom we depend so much for efficient production, have no technical education of any kind. Most of them have risen to their present position in the vacancies, caused by the departure of European and Muslim employees. It is, therefore, all the more necessary to ensure that we have a number of fully trained technical personnel available with us, to fill up these technical posts in future.

FOREIGN DELEGATIONS

The Government of India have of late been sending a large number of delegations of officers to foreign countries for studying the latest developments pertaining to their respective professions. It is, however, regrettable that so far not a single scientific officer conversant with the scientific problems of the Railways has been included in such delegations for studying up-to-date methods in foreign countries. Even the Technical Mission, which were sent to the U.K., U.S.A. and Australia, did not include any scientist from the Railways. Similarly, the Indian Railway Enquiy Committee, which visited the various Railway Centres in this country with a view to suggest economies, also did not have any Railway Scientist with them, except an officer brought from the U.S.A. for this purpose on a fabulous salary, who could not possibly have the same intimate knowledge of the scientific problems on the railway of this country, as our own Indian Scientists employed on the Railway. It is high time that due recognition were given to local Indian talent on Railways, who should be associated in all development schemes in the country as, besides scientific knowledge and training, they possess considerable practical experience of the various branches of technology as practised in this country.

OPERATIONAL DIFFICULTIES OF INDIAN RAILWAYS

It is not an easy job to run the Railways, as some of our public men are prone to think. The working and maintenance of the Indian Railways is far from simple. The public can hardly realise what a great amount of care the Railway administration takes for their comfort and safety. Every inch of the 35000 odd miles of Railway track is inspected daily. Every nut and bolt used in the Permanent Way is tested before use. All Railway requirements are tested before purchase to most stringent specifications, to avoid any mishaps occurring, due to any defect or the poor quality of the material. Even such items as communication and bunk chains are fully tested to breaking point before permitting their use in service.

At present, the greatest loss to the Railway revenue is caused by the ticketless travellers. During 1946-47, 4½ million travellers were detected travelling without tickets. This means one ticketless passenger for every 235 paying passengers. The Railways suffer a loss of over Rs. 8 Crores every year on this account. It is, therefore, very necessary for the public to cooperate with the administration to eradicate this evil, which is causing so much financial loss to their national industry.

The Hon'ble Minister of State and the Chief-Commissioner for Railways make very frequent visits to various Railway Centres, in order to establish personal contacts with the public, hear their grievances at first hand and adopt any useful suggestions that the public might make for the advancement of this, our greatest national industry. These are healthy signs; and I am sure the combined efforts made by these chiefs, coupled with the loyal and devoted services of the Railway Personnel-Officers and men—will surely raise the level of efficiency on the Railway to the highest pitch possible.

JAI HIND.

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